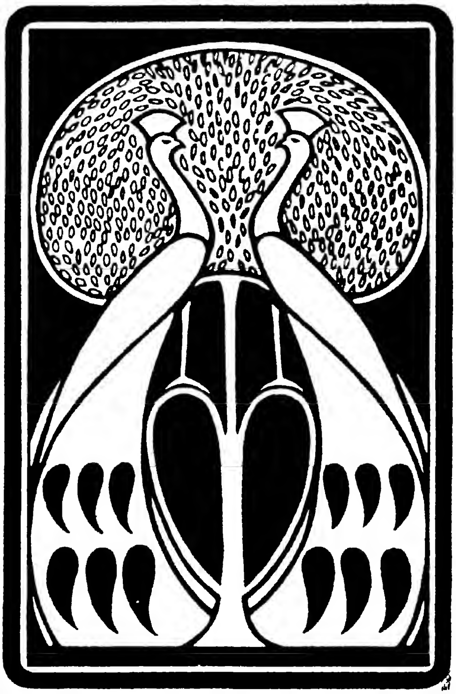
THE NATURAL HISTORY OF ANIMALS

The Animal Life of the World in its Various Aspects and Relations



4 VOLUMES

J.R. Ainsworth Davis

The Natural History of Animals

DIANA MONKEYS (*Cercopithecus Diana*)

These pretty little animals are characteristic members of the West African fauna, and belong to the group of Guenons (*Cerco pithecus*) The white beard and white crescent on the forehead are distinctive features, the latter having been fancifully compared to "Dian's bow", hence the popular and specific names Diana monkeys are typical tree forms, living in communities and, being gentle easily-tamed creatures, have always been favourite pets

DIANA MONKEYS (CERCOPITHECUS DIANA)

The Natural History of Animals

The animal life of the world in its various aspects and relations .

IN FOUR VOLUMES

BY

J.R. AINSWORTH DAVIS

Volume I

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PREFACE

Signs are not wanting that at the present time a revival of interest in Zoology is taking place, and this book is an attempt to help on the movement by pointing out the various lines of study and explaining in simple language the views of modern specialists. Every effort has been made to treat the subject-matter in such a way as to interest the general reader, while at the same time the needs of junior students, amateur naturalists, and teachers of elementary Zoology (including "Nature Study") have been steadily borne in mind.

All the larger popular books on Zoology which have so far appeared in English take the various animal groups seriatim, a time-honoured plan which is in many ways valuable and useful, but which fails to bring out the complex interrelations that exist between the different groups, the interdependence of animals and plants, and the bearing upon life of chemical and physical conditions. A due appreciation of the great complexity of the struggle for existence, and a realization of our comparative ignorance regarding adaptation of structure to habit, should open innumerable fascinating lines of really scientific study to many amateurs who are at present mere collectors of insects, birds' eggs, or shells. It may, however, be noted that Half-Vols. I and II to some extent meet the needs of those who prefer the old plan, for they review in brief the entire animal kingdom, as a necessary preliminary to the study of the Food of Animals, Animal Defences, &c., which constitute the subject-matter of the remaining volumes. Even in the first two half-volumes, however, comparisons are constantly instituted between different animals and different groups, in illustration of general principles.

The Introduction fully explains the plan of the work, and the lines which have been adopted in writing it, and books to which the Author is specially indebted are mentioned in the text. It is both mentally and physically impossible for one zoologist to know at first hand more than a small part of his subject, and for this reason full quotations, in preference to mere paraphrases, have been taken from the writings of many distinguished specialists, the sources in such cases being always indicated.

Many of the coloured plates have been drawn expressly for this book by Mr. A. Fairfax Muckley and Mr. William Kühnert, and others are by Specht, the distinguished delineator of animal life. Some of the black-and-white plates, and many of the text illustrations are also new, and the remainder have been taken or re-drawn from acknowledged sources. Mr. R. A. L. Van Someren has been so good as to place at my disposal a number of his interesting photographs of birds and birds' nests, while Prof. D'Arcy W. Thompson and Mr. W. H. Reeves have obligingly supplied me with other original photographs.

Special acknowledgment is also due to the authors and publishers of *Das Tierreich*, *Die Schöpfung der Tierwelt*, *Das Leben des Meeres*, and *Tierische Schädlinge und Nutzlinge* for their courteous permission to make use of other illustrations. My friend and colleague, Dr. H. J. Fleure, was so kind as to undertake the arduous task of editing the Index.

J. R. AINSWORTH DAVIS.

ABERYSTWYTH, *October, 1904.*

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INTRODUCTION

ON SCIENTIFIC METHOD

There are so many things to study in this world of ours, and outside it too, that it is no easy task to draw up a complete list of subjects. And supposing this done, it is a still harder task to determine the connection between the various subjects. This is not the place to attempt such a labour, and it will suffice for our present purpose to point out that in universities and other seats of learning it is customary to draw a distinction between "Arts" and "Science" courses, though the boundary line is indefinite. The Arts student is chiefly concerned with language, literature, mathematics, and philosophy; while the Science student, as such, is especially distinguished by the fact that he must work in the laboratory as well as in the lecture-room, at chemistry, physics, and biology, besides attending mathematical and, it may be, philosophical classes. It will thus be seen that mathematics and philosophy are considered common ground.

As this book deals with a branch of science, it may be well to enquire more particularly what "science" actually is. And here we have to distinguish between "pure" and "natural" science. "Pure" mathematics, the fringe of which is touched by all of us when we study arithmetic, algebra, and geometry, is an example of the former. It starts with certain self-evident truths, and makes deductions from these. The "natural" sciences, on the other hand, such as chemistry, physics, and biology, involve the study of facts by observation and experiment, these facts being afterwards used as a means

of determining the laws which regulate the universe. It is this special mode of procedure, the "*scientific method*", which distinguishes the natural sciences. The mode itself is known to everyone, though comparatively few could explain its exact nature. Huxley says (in his well-known address "On the Educational Value of the Natural History Sciences"): "Science is, I believe, nothing but *trained and organized common sense*, differing from the latter only as a veteran may differ from a raw recruit; and its methods differ from those of common sense only so far as the guardsman's cut and thrust differ from the manner in which a savage wields his club". The essence of the method consists in first ascertaining facts, resorting when necessary to experiment, then coming to some general conclusion based on the facts, and finally testing that conclusion by appeal to some case not previously investigated. Take, for example, the discovery of coal-seams by sinking a shaft through the chalk rocks at Dover. Prior to 1826 numerous observations had been made on the coal-bearing rocks in Somerset on the one hand and the north of France on the other hand, the conclusion being drawn that the two sets of rocks are practically identical. Twenty-nine years later, from these and many other additional facts regarding the distribution and arrangement of the coal-bearing rocks, Godwin Austen came to the conclusion that coal-fields exist far below the surface in the south-east of England. One such fact, the existence of coal below the surface-rocks of Oxfordshire, was determined by an experimental boring at Burford. Various considerations ultimately led to the selection of Dover as a suitable place for making a trial boring, which was begun in 1886 and completed in 1892. This boring proved the existence of a coal-field containing twelve seams of coal, the top of which is 1113 feet below high-water mark.[1]

Steps in above example of scientific method:—

1. The collection and arrangement of facts relating to the coal-fields of Somerset, north of France, and Belgium, some of the facts being determined by experiment.

2. Arrival at the following conclusion or generalization based on the said facts:—" Buried coal-fields exist in the area between

[1] The barest outline of the facts is here given. Details may be found in a pamphlet "On the Relation of Geology and Engineering," by Professor Boyd Dawkins, F.R.S.; being the "James Forrest" Lecture delivered at the Institution of Civil Engineers, Session 1897 98.—Published by the Institution, Great George Street, Westminster, London, S.W.

Somerset and north of France, the most likely locality being the neighbourhood of Dover".

3. Verification of the generalization. A shaft is sunk at Dover and a buried coal-field is actually discovered.

Among other striking examples of the scientific method may be mentioned the discovery of the Laws of Gravitation by Newton, and the discovery of the planet Neptune by Galle in the position where Adams and Leverrier independently prophesied a new planet would be found. It may be stated generally that when a theory or generalization enables us correctly to prophesy future events, that theory may be regarded as embodying one or more Laws of Nature. Thus, from calculations based on the theory of gravity, the position of the heavenly bodies at a given time can be predicted. Such calculations are to be found in the *Nautical Almanac*, published every three years, and these have always been found correct. Hence the Laws of Gravitation are regarded as Laws of Nature.

The scientific method is essentially experimental, and thus requires further illustration. Much can be done by observation only, but the progress of science would be exceedingly slow if it were not for *experiment*, *i.e.* the observation of facts under controlled conditions, enabling us to determine points which the mere watching of nature might never allow us to elucidate. Very good instances are found in the history of the "germ theory", which explains infectious diseases as only the action of microscopic organisms found within the body. Cattle, for example, are liable to be attacked by a most virulent complaint of the sort known as *anthrax* or *splenic fever*. It was noticed that the blood of animals which had died from this disease always swarmed with rod-shaped microscopic organisms, members of the large group of *bacteria* (microbes), the lowest subdivision of the vegetable kingdom. Mainly on the strength of this fact was founded the generalization—"Anthrax is due to rod-like bacteria in the blood". Then followed experiments designed to test the truth of this proposition. It was found that if healthy animals were inoculated with infected blood they quickly developed all the symptoms of anthrax, and died in the same manner and after the same time as in naturally occurring cases of the disease. A certain support

was thus given to the generalization, but the possibility that the rods might be the consequence and not the cause of anthrax was not excluded, and further experiments of more elaborate and painstaking nature became necessary. By well-known methods, "pure cultures" were made of the rod-shaped microbes, *i.e.* they were grown in an artificially-prepared medium, free from all other germs, in such a way that such other germs continued to be excluded. Healthy animals were then inoculated from these pure cultures, with the result that typical anthrax at once manifested itself. In this way the original generalization was experimentally verified. By similar methods of procedure many other diseases have been proved to be due to the noxious action of specific microbes. Other instances of the experimental method will be given in the course of this work.

In all such cases the value of the *imagination* can hardly be overestimated. To frame a reasonable generalization from a mere collection of facts requires a mental jump, so to speak, and the man of real genius in the scientific world—the "epoch-making" man—is he who can make such leaps in the dark with the best prospect of alighting on solid ground.

THE STUDY OF ANIMALS

SUBJECT-MATTER OF BIOLOGY.—All material objects are composed of what is known as "matter", about which all that can positively be stated is that it occupies space, takes up room, as we may say. Matter is liable to undergo change, and these changes are dealt with by chemistry and physics; by the former if they involve modification in composition; by the latter if they do not. One particular kind of matter is distinguished by the possession of life, which is recognized by its effects, though we are profoundly ignorant of its real nature. *Biology*, the science of life (Greek *bios*, life; *logos*, a discourse), deals with living matter, that is to say, with plants and animals, from all possible points of view. As organisms are constantly undergoing both chemical and physical changes, it is obvious that a knowledge of physics and chemistry is, to say the least, of immense value to the biologist. It has even been suggested that life will some day be explained by chemical and physical laws; but, even if

such mechanical explanation be possible, that day is far distant, for at present our knowledge of the composition of living substance is exceedingly crude and imperfect.

SUBDIVISIONS OF BIOLOGY.—So vast a subject as that dealing with life obviously needs subdivision for purposes of convenience, and it is customary to recognize two main branches, *Botany* and *Zoológy*, dealing with plants and animals respectively (Greek *botane*, a plant; *zōŏn*, an animal). This does not mean, however, that there is any sharp boundary between the animal and plant worlds. No doubt it is easy to tell the difference between a higher plant and a higher animal, though it might not be so simple to point out in exactly what the difference consists; but when we come to microscopic organisms, difficulties soon arise, and the usual tests break down. Well-defined lines of division but rarely occur in the organic world.

In this book we shall confine ourself in the main to *Zoology*, or *Natural History* as it is often called, but reference to the vegetable kingdom will have to be made in many connections, owing to the obvious fact that there is a very intimate relation between plants and animals.

WAYS OF STUDYING ZOOLOGY.—Animals, of course, can be studied from various stand-points, some of which will here be mentioned, as they form a basis for the splitting up of the subject. The accumulated observations of thousands of observers constitute such a mass of knowledge (one, too, that is ever growing), that it is a hopeless task for any individual to acquaint himself with what is already known, and even the professional zoologist can do no more than acquire a general knowledge of his subject, with special knowledge of some limited branch. And when we reflect that, after all, the known is very small, while the unknown is stupendously large, in amount, the present tendency to specialization becomes fully intelligible. It is nevertheless quite easy for anyone of average intelligence to acquire sound general ideas regarding the various possible modes of attacking the subject.

1. *The Stand-point of the Naturalist.*—Zoology to the naturalist is essentially an open-air study. He delights in watching living animals with the view of finding out all he can about their habits, naturally learning at the same time a great deal about their external features, and also finding it necessary to know something

about classification. Nearly every country child is a naturalist in this sense, not to mention many older persons, though for some decades there has been an unfortunate tendency to ignore habit and pay overmuch attention to what we may call laboratory zoology. The most admirable type of English naturalist is undoubtedly Gilbert White, author of the well-known book, *The Natural History of Selborne*, in which he records observations made by him during his residence there. Selborne was his native place. Born in 1720, he later on filled a curacy in the neighbouring parish of Faringdon (1755–84), ending his life as curate of Selborne (1784–93). The late Richard Jefferies, himself an ardent naturalist, speaks of White in a preface written to the Camelot edition of the *Natural History*. After quoting an observation as to the way the garden warbler sips honey from the Crown Imperial, Jefferies remarks:—"Here we . . . see how different minds may trace out the bearing of the same fact. The old naturalist at Selborne simply records it in language which could not be better chosen, highly delighted evidently, and taking a deep interest in it for its own sake. In the same manner, anyone who has a taste for out-of-door observations may study natural history without any previous scientific learning. . . . Part of his (White's) success was owing to his coming to the field with a mind unoccupied. He was not full of evolution when he walked out, or devolution, or degeneration. He did not look for microbes everywhere. His mind was free and his eye open. To many it would do much good to read this work, if only with the object of getting rid of some of the spiders' webs that have been so industriously spun over the eyesight of those who would like to think for themselves." Fortunately a reaction has been setting in of late in favour of natural history, and we are beginning to realize that far less is known about the habits than about the structure of animals.

Among charming books of the kind the following may well be mentioned:—

Bates—*Naturalist on the Amazons.*
Belt—*Naturalist in Nicaragua.*
Brehm—*From North Pole to Equator.*
Buckland—*Logbook of a Fisherman and Naturalist*, and *Curiosities of Natural History.*
Darwin—*A Naturalist's Voyage.*
Forbes—*A Naturalist's Wanderings in the Eastern Archipelago.*
Fowler—*Tales of the Birds*, and *A Year with the Birds.*

Gosse—*A Year at the Shore*, and other works.
Hickson—*A Naturalist in North Celebes.*
Hudson—*The Naturalist in La Plata.*
Jefferies—*Red Deer*, and other works.
Lloyd Morgan—*Animal Sketches.*
Moseley—*Naturalist on the "Challenger"*
Semon—*In the Australian Bush.*
Fred Smith—*Boyhood of a Naturalist.* A little book which breathes the spirit of Gilbert White in every page.
Wyville Thomson—*The Depths of the Sea*, and *Voyage of the "Challenger"*.
Thoreau—*Walden.*
Wallace—*Malay Archipelago*, and *Tropical Nature.*
Waterton—*A Naturalist's Wanderings in South America.*

The camera has lately with great success been pressed by the brothers C. and R. Kearton into the service of outdoor zoology, but this has not been done without untiring patience and the expenditure of a very large amount of time. Their books, *With Nature and a Camera*, *British Birds' Nests*, and *Wild Life at Home*, are ideally illustrated.

2. *The Stand-point of Classification.*—Such an enormous number of animals exist (considerably more than a million kinds being now known to science) that as a matter of convenience it is found necessary to classify them, that is, to arrange them into groups according to their likenesses and differences. Animals have always played such an important part in the lives of human beings, as sources of food, clothing, ornament, &c., and as objects of interest, that even the most primitive languages contain words for different kinds of animal. The names of those animals which have been longest domesticated, such as ox and sheep, are thus found to be of extremely ancient origin, and the same is true in the case of certain widely distributed and conspicuous wild forms, such as mouse, midge, beaver, and eel. But in addition to this we have class-names, such as bird, fish, snake, &c., which constitute the unconscious beginning of a rough classification, as they embody the fact that many kinds of animal collectively form a larger group, *e.g.* that of birds. But besides this we learn from the literature of many cultured peoples that even in early times deliberate attempts at classification were made. An example of this may be found in Genesis, i. 26, where we read, ". . . let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, . . . and over every creeping thing

that creepeth upon the earth". Solomon is represented (1 Kings iv. 33) as using the same fourfold division, except that the word "beast" is used instead of "cattle". The creatures included under the former term are evidently those which are popularly called "quadrupeds" at the present day, while scientifically they are known as "mammals". The lower terrestrial forms of life are embraced by the comprehensive term "creeping things". The word "insect" was used in English till comparatively recently much in the same way. This crude classification is clearly based on the nature of the media in which the various animals live, *i.e.* it is a division into animals living respectively on the land, in the water, and in the air, land animals being further subdivided into higher and lower forms. Such a grouping is of necessity very superficial, for habitat is a very misleading guide to affinity or likeness. Whales, porpoises, and seals are as much "beasts" as cows and sheep, though to this day we speak of whale and seal "fisheries". And further, such a group as "creeping things" or "insects" (in the old sense) contains such a miscellaneous assortment of creatures that it may be looked upon as a mere receptacle for forms finding no place in the other three subdivisions.

The first man to place zoology on a scientific basis was the Greek philosopher Aristotle (384–322 B.C.), "perhaps the greatest and most truly scientific man in the highest sense of the word that the world has ever known" (Milnes Marshall), who, though the study of animals was not the one to which most of his time was devoted, has nevertheless been styled the "Father of Natural History". Aristotle had a very considerable knowledge of the habits and structure of the animals known to him, about 500 in number; he was impressed by the fact that the animal kingdom exhibits a transition from lower to higher, and devised a scientific system of classification based on structure. His great merit here lies in the fact that he divided the animal kingdom into two groups,—(A) Animals with red blood and a backbone, and (B) Animals without red blood and no backbone, a division which corresponds precisely with the modern one into Vertebrata (Backboned animals) and Invertebrata (Backboneless animals), though we now know that the distinction as to blood is not quite so absolute as Aristotle supposed. He further recognized five classes among the backboned animals (viviparous

quadrupeds producing living young, egg-laying or oviparous quadrupeds, birds, fishes, and whales), and four among the backboneless (molluscs, scaly animals, animals with soft scales, and insects).

Unfortunately, after the time of Aristotle zoology progressed in a backward direction, and during the Middle Ages all sorts of absurd ideas gathered around it. A fresh start was made by Wotton (1492–1555), a native of Oxford who afterwards became a London physician. He went back to the classification of Aristotle, and from his own observations enlarged upon it. Further work in the same direction was afterwards done by the Swiss professor, Gesner (1516–65), and by the Englishman, John Ray (1628–1705), work which led up to the better known and more extensive labours of Karl von Linné, usually known by the name of Linnæus (1707–78). As professor of Natural History in the Swedish university of Upsala, he wrote his *System of Nature*, which must ever remain a classical work, and in which are laid down the foundations of our modern classification. Comparing the plant and animal worlds to armies, he instituted a series of subdivisions named, beginning with the largest, class, order, genus, and species, metaphorically equivalent to the legions, cohorts, maniples, and contubernia of a Roman host. His animal classes were six in number. Linnæus also introduced the system of giving each kind of animal a double name, the first being that of the genus, the second that of the species. We find living in Britain, for example, three kinds or species of hare-like animals, all belonging to the genus *Lepus*, and called in popular language rabbit, hare, and Alpine or Irish hare. The double scientific names of these are respectively, *Lepus cuniculus*, *Lepus timidus*, and *Lepus variabilis*. The utility of such names is obvious, for if in recording observations on, say, the rabbit, we speak of it as *Lepus cuniculus*, a zoologist of any nationality whatsoever will know to what animal we are referring, while merely to employ the popular name might lead to great confusion. It will be noticed that the first or generic name is comparable to a surname, while the second or specific name may similarly be compared to a Christian name. The generic name is placed first merely as a matter of convenience, just as in an official list of human beings, such as a list of voters, it is found more convenient to give first place to the surname. By universal consent, scientific names are almost entirely taken from

the dead languages, Latin and Greek, as these are studied by all civilized nations. Unfortunately many such names are clumsy, and some are barbarous mixtures of Latin and Greek; but in spite of this the system is a good one.

The classification of Linnæus, like that of Aristotle, is a "classification by definition". As a result of observation, certain groups are *defined*, *i.e.* their essential characters are given, and newly-discovered animals are placed in this or that group according as they are found to possess or lack certain features. Such a classification assumes the existence of sharp boundary lines in nature, and is really based on the idea that the different kinds or species of animal were created separately and independently. The Linnean Class of *Mammals*, for instance, is defined as being a group of viviparous animals, possessing a four-chambered heart and hot red blood. Any newly-found kind of animal possessing these features would be considered a mammal. In framing such a classification comparatively few prominent features are selected, and more attention is paid to the boundary lines than to the resemblances between the animals constituting a group. This particular method of subdivision is by no means confined to natural history; an example from another province is afforded by the classification of Britons according to income for income-tax purposes. Those individuals falling well within a subdivision are of no special interest, but those only just coming up to the amount of a particular class are objects of commiseration to themselves as paying a particular percentage with the least reason, while on the other hand those who only just escape falling within a more highly-taxed section have a special interest for the assessors.

After the time of Linnæus the rapid progress of more accurate observation, now aided by fairly good microscopes, gradually led to the conviction that classification by definition is far from satisfactory, and to a reaction against the current idea that the different groups of the animal kingdom form a linear series, a gradual ascent from low to high in, so to speak, a straight line. The next important scheme of classification, which we owe to the great French anatomist Cuvier (1769–1832), is one by "type". This system lays stress upon the resemblances between the members of a group rather than on the boundary lines between different groups, or, in other words, "The class is steadily fixed, though not precisely limited; it is given, though not circumscribed; it is

determined, not by a boundary line without, but by a central point within; not by what it strictly excludes, but by what it eminently includes; by an example, not by a precept; in short, instead of a definition we have a type for our director" (Whewell). Cuvier was the first to recognize the fact that the different groups of animals are related to one another like the branches of a tree, and not like successive portions of a straight line. He recognized four great branches—Vertebrates, Molluscs, Articulates, and Radiates, each distinguished by its special type of structure.

Since Cuvier's time it has come to be more and more recognized that in a "natural" classification, *i.e.* one having regard to as many distinctive features as possible, in contradistinction to an "artificial" system which regards only one or a few arbitrarily chosen characters, the groups of animals must be represented diagrammatically by a tree, in which the large branches represent the large groups, their subdivisions the smaller groups, and the leaves individuals. This conclusion has been greatly supported and extended this century by the study of extinct animals, placed on a scientific basis by Cuvier himself; and by the teachings of development or embryology, a zoological branch of which the foundations were firmly laid by von Baer (1792–1876).

The real meaning of this tree-like arrangement of organisms was at first a mystery, but, thanks more particularly to Charles Darwin and his contemporary Alfred Russell Wallace, who is fortunately yet among us, we now understand it to be an expression of an actual blood-relationship—to be, in fact, a veritable genealogical tree, the outcome of a process of evolution. And hence classification at the present time is a "classification by pedigree", and is perfect, in so far as we are successful in arranging animals according to their actual affinities.

3. *Zoology as regarded by the Morphologist or Student of Animal Form.*—One of the main subdivisions of modern zoology is the branch dealing with the shape or form of animals, using these words in their broadest sense. This part of the subject is *Animal Morphology* (Gk. *morphe*, form; *logos*, a discourse); and it deals not only with the external characters, the outward form, but also with the structure or inward form, as revealed by dissection and by the use of the microscope. The external characters of animals were naturally those first noticed; then came the study

of their anatomy, to which Cuvier gave an immense impetus; and lastly, the investigation of minute structure or histology (Gk. *histós*, a texture), which, though the compound microscope was invented near the end of the sixteenth century, practically began as a serious study with Malpighi and others nearly a hundred years later, and has rapidly advanced up to the present time, every successive improvement of the microscope leading to the acquisition of more extended and more accurate knowledge. The microscope, too, besides vastly increasing our knowledge regarding the structure of well-known animals, has thrown open to investigation a once unsuspected world of minute forms, just as the telescope has extended our field of observation in the other direction.

Morphology, however, is not content with merely cataloguing facts regarding the structure of different sorts of animals. It compares and classifies these facts, and endeavours, as far as may be, to explain them in the light of the evolution theory. Innumerable problems are met with, many being of the most fascinating description, and the solution of these constantly engages the attention of numerous expert workers. Some of these questions are naturally very abstruse, but many of them, when properly presented, are certain to excite the interest and arrest the attention of almost any intelligent person. As a good example of such a problem and its solution we may take the nature and origin of teeth.

Teeth, as seen, for example, in a dog or cat, are hard bodies having a certain complex structure, and developed by the lining of the mouth-cavity. The question may be asked—"How have teeth been evolved, and are any other parts of the animal body comparable with them?" No answer can be given to this unless the comparative method be adopted (a method we owe to the illustrious German biologist, Johannes Müller, and which is of supreme importance in zoological matters) and a general survey taken of the backboned animals generally. Mammals, birds, and amphibians do not afford a solution of the problem; but on coming to fishes we find that many of them possess numerous hard defensive bodies in the skin known as "placoid scales", which vary greatly in shape in different cases. Now these scales greatly resemble teeth in structure, and if in a dogfish we closely examine the neighbourhood of the mouth, it will be found that

the placoid scales gradually become more and more tooth-like as regards shape, all the intermediate stages being found. To this it may be added that the mouth-cavity develops as a pit or depression in the surface of the body, so that its lining is really specialized skin, and might be expected to produce similar structures to those characteristic of skin. Piecing together these various facts we arrive at the conclusion—"Teeth have resulted from the modification of scales belonging to the mouth-cavity", a conclusion which is rendered still more probable when we find that teeth are by no means limited to the edges of the jaws, but may also be found (in some fishes, reptiles, &c.) on the roof and other parts of the mouth-cavity. That teeth should persist in animals like mammals, which have long since lost the original scaly covering of remote ancestral forms, is explained by the principle of "change of function", often exemplified by organs which are out of work from having lost their original job. This is a case of primarily defensive structures which have been pressed into the service of the digestive system, though they may also, in certain instances, again be modified for defence and offence on new lines.

4. *The Physiologist's Stand-point.*—Students of physiology are, like naturalists, interested in the life-manifestations of animals, but their enquiries are more subtle, and aim at determining the uses or functions of the various parts revealed by anatomy and histology. To determine the nature of life is the final aim of the physiologist. The several departments of zoology are so intimately related that they are briefly described here under separate headings merely as a matter of convenience. This is particularly true of physiology and morphology, which are so closely interwined that it is impossible to separate them. The study of form would be extremely dull and largely profitless without some knowledge of function, and the study of function presupposes a preliminary knowledge of form. For example, a far more vivid interest is imparted to a description of the structure of the eye if the uses of its various parts are kept in view, while any explanation of vision would obviously be impossible were the related anatomical facts ignored. A very good example is afforded by the tooth problem, dealt with in the last section, where questions both of morphology and physiology are involved.

5. *The Embryologist's Stand-point.*—The study of form and

function when applied to animals before they reach the adult condition is known as Embryology or Development. From very early times it attracted a considerable amount of attention, but was first placed on a really scientific footing by von Baer (1792–1876), and as the result of the labours of many specialists, notably Francis Maitland Balfour (1851–82), formerly Professor of Animal Morphology in the University of Cambridge, and the Russian zoologist Kowalewsky, is now an important, perhaps even an overestimated, branch of the subject. As in so many other cases, the interest of the facts has been enormously increased as a result of the influence of the theory of evolution. Consisting as the subject-matter does of the life-histories of animals, it has always formed part of the work of the field naturalist, who has delighted in the mysterious growth of frog from tadpole, or the passage of caterpillar into chrysalis, and that again into the butterfly. Such interest had quite a new turn imparted to it when the evolutionist formulated the "Law of Recapitulation", according to which, in the words of Milnes Marshall, "every animal in its own development repeats its history, climbs up its own genealogical tree". Thus interpreted, the fish-like tadpole points to the descent of frogs from ancestors which in many respects possessed those characters which we now associate with fishes. There has been, however, a tendency to exaggerate the importance of this law.

6. *The Stand-point of Distribution.*—Under this heading two things call for consideration—(*a*) Distribution in Space and (*b*) Distribution in Time.

(*a*) *Distribution in Space.*—Everyone knows that different countries are inhabited by different sorts of animals, *e.g.* that kangaroos are to be found in Australia, ostriches in Africa, and sloths in South America. Until the rise of the evolution theory no explanation was given of such facts, except that animals have been created separately where we now find them. This was the doctrine of "special creation", and if we adopt it, the study of distribution can be little more than a recording of facts. Admitting however, the truth of the evolution theory, it becomes possible to give a reasonable explanation of many curious and at first sight anomalous instances of the sort. We have, for example, the well-known case of the tapir, an animal somewhat resembling the pig in appearance but possessing a short proboscis. These creatures are only found in South America and the Malay region. We know,

however, from geological evidence, that animals of the kind formerly existed in North America, Europe, and Asia, and their present occurrence in two widely isolated areas is thus explained, extinction (dying out) having taken place in the intervening tracts owing to the competition of other forms of life.

(*b*) *Distribution in Time.*—As will be fully explained in the sequel the study of geology enables us to some extent to carry back the study of animal life to periods immensely remote from the present, and to construct a history of animals in chronological order. As, from an evolutionary stand-point, we might expect, there has been on the whole a progress from low to high, and it is even possible to work out with some approach to accuracy the pedigrees of certain existing groups. We learn that some forms, including Man himself, are of comparatively recent origin, while, on the other hand, there are many groups of animals which have no living representatives. Much light is also thrown, as indicated above in the case of the tapirs, upon problems of distribution in space.

7. *The Utilitarian Stand-point.*—We may include under this heading not only economic zoology, dealing with the animal kingdom as a source of food, clothing, ornament, &c., but also facts regarding animals as they appeal to the sportsman, the keeper of pets, and the lover of the beautiful.

Economic zoology, though largely statistical, also involves issues of more general interest, such as the improvement of farm stock, fish-hatching, oyster culture, and bee-keeping. Facts observed from a purely practical stand-point in these and other departments of applied zoology have often proved invaluable to theorists, as appears abundantly in the pages of Darwin's great work, *Plants and Animals under Domestication*; while, on the other hand, researches conducted by theorists have repeatedly borne practical fruit.

As regards animals in a sporting connection, it commonly happens that sportsman and naturalist are combined in the same individual, and our knowledge of the habits of many animals is largely derived from this source. Such books as Sir Samuel Baker's *Wild Beasts and their Ways*, Shield's *The Big Game of North America*, and Chapman's *Wild Norway*, *Wild Spain*, and *Bird-life of the Borders*, among innumerable others, illustrate this point.

Animal Æsthetics, dealing with animals as objects of beauty,

is a branch of zoology which can scarcely be said to be organized, but it is a commonplace to say that animal form and colour have always proved more or less attractive to painters, sculptors, and human beings in general. The uses of animals, parts of animals, or animal products for ornamental purposes fall to be treated of by economic zoology. The old idea was that the beautiful or striking forms and colours of plants and animals were intended solely for the gratification of human tastes. Modern theory interprets them as playing some part with reference to the organisms themselves. Predatory animals are often coloured so as to render them inconspicuous to their prey, while, on the other hand, many creatures are thus protected to some extent from their enemies. Conspicuous colours and markings, such as those of the wasp, may be of "warning" nature, acting as danger-signals, while some of the most beautiful tintings are plausibly explained as "courtship colours", *e.g.* the brilliant scarlet hues assumed by the male stickleback during the nesting season.

8. *The Philosophic Stand-point.*—The groundwork of zoology undoubtedly depends on observation of the various classes of facts enumerated under the preceding headings, but this is not the highest development of the subject. Here the palm must be given to zoology considered as a branch of philosophy, aiming at the explanation of the facts relating to animal form, function, and distribution by means of theories founded on such facts. Thus we see an otherwise chaotic mass of material falling under general laws, and assuming orderly proportions, as in the sister sciences of astronomy, chemistry, physics, and geology. All intelligent workers in the zoological field, whatever may be their special branch--form, function, development, classification, or what not,-adopt the philosophic stand-point more or less, for without a reasonable admixture of theory the subject-matter of zoology is but as bread without leaven, or meat without salt.

Although speculation, often crude, it is true, has always been more or less associated with the study of living beings, its influence as a revolutionary and stimulating agent undoubtedly dates from 1859, the year in which Darwin and Wallace formulated their theory of evolution. And it is the especial glory of zoology that the theory then propounded has had the most wide-reaching influence, not upon biology alone, but upon every branch of learning. For biology connects on the one hand with subjects

such as chemistry, physics, and geology, and on the other with the study of mankind and the works of man. From morphology and physiology we pass, though not without huge gaps in knowledge, to the study of mind (psychology), sociology, political economy, law, ethics, and history, while even linguistic students are nowadays confronted with problems best explained on an evolutionary basis.

THE PLAN OF PRESENT WORK

Most popular modern books on zoology written in English deal with the various groups seriatim, beginning with the highest forms and ending with the less familiar creatures, our knowledge of which is mainly due to the microscope. Of such books Cassell's *Popular Natural History* and Lydekker's *Royal Natural History* may be mentioned as admirable types.

This plan is not here followed, but an attempt is made to treat the subject in a comparative manner, taking function as the basis, and illustrating the various points as they occur by examples taken from all or many of the animal groups. It is believed that this plan is better adapted than the other for bringing into relief the most interesting facts and theories of modern zoology. Such a mode of treatment was once much in vogue, both in lecture courses and in books like the late Dr. Carpenter's *Animal Physiology*.

A sketch of *Classification* will first be given, so as to familiarize the reader with the chief groups of animals and the range in form presented by the animal kingdom, especially as regards external characters. Special attention will be given to familiar forms, particularly such as are native, and those which may be commonly seen in zoological gardens. This will be followed by a section on the *Food and Feeding of Animals*, with special reference to interesting modifications and adaptations resulting from the various ways in which animals get their livelihood, if one may use the expression. *Animal Defences* will next be treated, and this section is closely connected with the preceding, as means of defence are mainly necessary to protect animals from the attempts of other animals to eat them. *Breathing and Movement*, as two primary functions, will form the subject of the next two sections, under which will be fully treated adaptations for

breathing in air and in water, and modes of movement aboveground, underground, in water, and in air.

The subject of *Development* will next be dealt with, and typical life-histories will be given, after which such subjects as *Care of Eggs and Young* and *Animal Homes and Dwellings* will receive attention.

The lower functions of animals having been dealt with in the earlier sections of the book, the higher functions will next be considered, and some of the more important details regarding the structure and function of *Nervous System* and *Sense Organs* will be presented. This will be followed by a section on *Instinct* and *Intelligence*, activities involving the operation of the organs described in the preceding section. Such matters as the migration of mammals and birds, the habits of social insects (ants, bees, wasps, &c.), and the "homing instinct" of certain forms, will here receive treatment.

In the remaining part of the book considerable space will be devoted to the wide and interesting questions connected with the *Association of Organisms*. The first thing here to be dealt with will be the various kinds of association obtaining between plants and animals, such as the relation of insects to flowers, ants to various plants, insectivorous plants, and galls produced by insects. Next will follow an account of the chief kinds of association between animals of the same species, including chapters on Mating and Courtship, and on Animal Communities, in so far as the last subject was not treated of in relation to instinct. Different kinds of association between organisms of different species will be the last heading under this section, and will include all the various sorts of relation known to biologists, among these being *Commensalism*, where messmates are associated; *Mutualism*, where there is an intimate beneficial union; and *Parasitism*, in which unwelcome guests prey upon a "host".

The concluding sections of the book will be devoted to Utilitarian Zoology, Distribution in Space and Time, and Philosophical Zoology.

Under *Utilitarian Zoology* we shall have occasion to deal with animals as the foes and friends of man, and this will naturally involve some description of the chief ways of coping with foes, *e.g.* agricultural pests, and some of the methods, *e.g.* pisciculture, by which the usefulness of animals is enhanced. Some space

will also be devoted to domestic animals, animal pets, sporting zoology, and animal æsthetics.

Distribution in Space will be illustrated by typical cases, involving a brief exposition of leading principles. A short account of life as modified by various surroundings will follow, and such subjects as deep-sea, fresh-water, and underground faunas will here receive treatment.

Distribution in Time will involve a sketch of the ancient life-history of the earth, under which the most interesting extinct forms will, of course, be described.

The section on *Philosophical Zoology* will of necessity be chiefly occupied by some account of the Theory of Evolution, and of related matters, such as the question of Heredity.

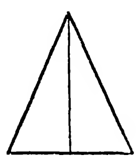
CHAPTER I

CLASSIFICATION—STRUCTURE OF MAN TAKEN AS A TYPE

GENERAL CONSIDERATIONS

In considering any scheme of classification, and in subsequently dealing with the various functions of animals, reference will constantly have to be made to external characters and to various sets of organs and their mode of action. It would therefore appear desirable, in order to clear the ground, to give some account of certain points of fundamental importance, and this can perhaps best be done by fixing our attention at start upon some familiar organism. It is undoubtedly the best plan to begin with the known, and from this to proceed to matters regarding which the majority of readers are more or less ignorant, though throughout this book no technical knowledge will be assumed. And for various reasons, such, *e.g.*, as that a very large number of persons have some elementary acquaintance with Human Anatomy and Physiology, it is deemed advisable to begin this chapter by a brief account of the structure and life-functions of man himself.

SYMMETRY.—The body of a human being, and the same is true for the common domestic animals, is built with a certain sort of regularity to which the name of two-sided or *bilateral symmetry* is applied. And to fully appreciate what is meant by this we must suppose the body to be placed with its front surface downwards, as is permanently the case in a dog, rabbit, or frog. This is clearly necessary, for if we are to compare man with the lower animals the same relative positions must be assumed for purposes of description.



Bilateral symmetry means, then, that the body can be divided into two corresponding halves in one way and one way only. Simple examples of this kind of regularity are afforded by an isosceles (or equal-sided) triangle, many leaves, and most of the

so-called irregular flowers. The two halves, conveniently termed right and left, are not exact counterparts, but are what has been termed mirror-images. That is to say, if one half be placed with its cut surface against a mirror its reflection will correspond to the missing half. But bilateral symmetry in an animal involves more than a distinction between right and left, it means also, or the terms right and left could not be properly used, a distinction between front (anterior) and back (posterior) ends. Not only so, but we further perceive that an upper (dorsal) surface can be recognized as distinct from an under (ventral) surface. These points come out somewhat more clearly in lower animals

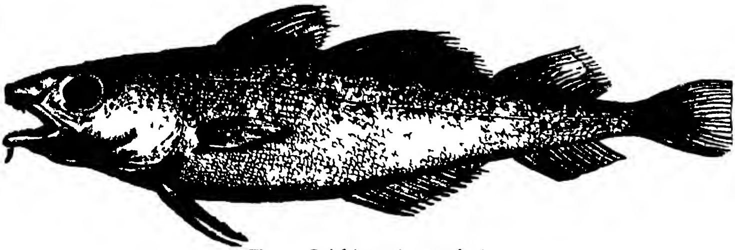


Fig. 1.—Cod fish (*Gadus morrhua*)

The pelvic fins are seen under the throat and a pectoral fin on side of body above them

than in man. Take, for instance, a fish, say a cod (fig. 1). The anterior end is clearly the head-end, the end which under ordinary circumstances goes first, and which, therefore, naturally bears the mouth, and is provided with the most important sense organs, such as those of smell, sight, and hearing—here most conveniently situated, as organs by which the presence of food, or it may be of enemies, is mainly perceived. The posterior or tail end bears in this animal a powerful propeller in the form of a fin. We also see marked differences as regards the dorsal and ventral surfaces, having an obvious relation to the needs of the animal. These differences are partly of form and partly of colour. Nothing need here be said on the former head, but as to the latter we note that the dorsal surface is dark while the ventral is pale, an arrangement which, as will be fully explained elsewhere, makes the animal match its surroundings much better than would otherwise be the case. Bilateral symmetry, therefore, is essentially a distinction between right and left, anterior and posterior, dorsal and ventral. It may be taken as an

expression of the fact that the external influences which act upon the body are different in different directions, and we must seek in this fact an explanation of the origin of such symmetry. Were external influences the same in all directions we might expect the body to be spherical, but as this obviously can rarely or never be the case, we are prepared for the fact that absolutely spherical animals scarcely exist. In certain fixed forms, however, as coral polypes (fig. 2) and the like, we do get radial or star-like symmetry, where there is a distinction between upper and lower, but none between right and left, or posterior and anterior. In such a case the part of the animal facing upwards is exposed to the light, while the part facing downwards is shaded. All parts of the margin, however, are, on the whole, liable to be acted on in much the same kind of way—by light and other external influences.

Fig. 2.—Red Coral (*Corallium rubrum*) magnified. A, Polypes; B and C, Embryos.

LIMBS.—We further notice, as regards a fish, that, in addition to the unpaired expansions or fins, which project from the middle line of the body, there are four paired fins, which may with propriety be termed limbs, *i.e.* a pair of anterior or pectoral fins and a pair of posterior or pelvic fins. These are all unjointed, paddle-shaped expansions, with quite continuous margins. Let us now turn to the Frog, which begins life as a fish-like tadpole. Fixing our attention upon an individual which is beginning to turn into a frog, we shall distinguish all the features which belong to the bilateral state; but the limbs, instead of being fin-like, are divided transversely into certain regions, and are also provided with digits. Both of these features have relation to the semi-terrestrial life which the adult is destined to lead. Taking next an adult frog, we find the limbs well-developed while the long swimming tail which was so conspicuous a feature in the tadpole has entirely disappeared. Nevertheless the trunk clearly possesses anterior and posterior ends, while the distinction between dark dorsal and light ventral surface is equally clear. Suppose the frog now to

stand on its hind-legs in the erect attitude commonly attributed to it in illustrated books of fables and the like, and we shall see that the anterior and posterior ends of the trunk become upper and lower, while the ventral surface faces to the front, and the dorsal surface faces, if one may so speak, to the back. A frog thus disposed has a comic resemblance to a human being, and the reason is clear—the erect attitude in both cases brings about the same relative positions of ends and surfaces.

Let us next examine the two pairs of limbs possessed by Man. A very cursory inspection will show that they are divided into similar regions, and this is best expressed in tabular form

Anterior or Fore Limbs.	*Posterior or Hind Limbs.*
1. Upper arm.	1. Thigh.
2. Forearm.	2 Lower leg.
3. Hand.	3. Foot.
(*a*) Wrist.	(*a*) Ankle.
(*b*) Palm region.	(*b*) Sole region.
(*c*) Thumb and four fingers.	(*c*) Great toe and four others.

STRUCTURE OF THE HUMAN BODY

It was long ago pointed out by Huxley that the body, apart from the limbs, may be looked upon as a double tube. When halved longitudinally, and the internal organs removed, this can be very clearly seen (fig. 3), and the same thing is obvious in the similarly divided carcasses of sheep and other animals to be seen hanging up in a butcher's shop. The two tubes may also be clearly seen in a cross section. One of them is dorsal, the other ventral. The latter forms in the trunk the large cavity of the chest and abdomen, being divided into two parts corresponding to these two regions by a partition, the mid-riff or diaphragm, which is partly fleshy, partly fibrous. The thoracic part contains the heart, lungs, most of the gullet, and part of the large blood-vessels; while the abdominal part contains the bulk of the digestive organs, the kidneys, and various other structures. The dorsal tube in the trunk is comparatively small, and consists of a narrow canal running down within the backbone and enclosing the spinal marrow. It is continued through the neck, and in the head expands greatly into the large cavity of the cranium or brain-case, in which the brain is situated. The brain and spinal

marrow are continuous with one another. One can scarcely say that the ventral cavity is represented at all in the neck or head.

N.B.—In the following account of the human body it is supposed to be placed with the front (ventral) surface directed downwards and the back (dorsal) surface directed upwards, as in a quadruped. The "upper" and "lower" parts, commonly so called, will be termed anterior and posterior respectively, unless the ordinary words happen to be specially convenient, as *e.g.* when the arrangement for supporting the weight of the body are described.

Fig. 3. Trunk in Longitudinal Section. A, Ventral wall of thorax; B, Diaphragm; C, Ventral wall of abdomen. To right of E and D is seen backbone in section with spinal canal.

The body of a large and complicated animal such as a human being requires hard parts to serve as a protection to the delicate internal organs, to act as a stiffening or support, and to furnish points of attachment to the bands or masses of flesh (muscles) by means of which movements are effected. Such hard parts constitute the *skeleton*, which may be either external (*exoskeleton*) or internal (*endoskeleton*), both being present in many animals. In Man the *exoskeleton* is not so well developed as in many other cases, but it is present in the form of the horny outer layer of the skin (epidermis), and the hairs and nails which grow out from this. Without epidermis the numerous blood-vessels in the deeper part of the skin (dermis) would constantly be wounded, while the many nerves there ending would be the source of constant pain. Any bald-headed person can testify to the value of hair as a protection from extremes of temperature and damp, while nails help to protect the sensitive ends of the fingers and toes, though this, of course, is not their only or even their chief use.

THE ENDOSKELETON.

The endoskeleton (figs. 3–7) is built up from bone, gristle (cartilage), and tough fibrous material (connective tissue). We may conveniently distinguish between the *axial skeleton* (supporting the head, neck, and trunk) and the *skeleton of the limbs*. The

former consists of *backbone*, *skull*, *ribs*, and *breast-bone*. It will be perhaps best to begin with the first of these.

The Axial Skeleton.

1. *The Backbone.*—A glance at the backbone, or, as it is often called, the *vertebral column* (fig. 4), shows that it is thrown into a series of curves, which converts it into a kind of spring for breaking the shocks to which the body is constantly liable, and which if transmitted to the brain would often result in stunning, or it might be even more serious injury. A further obvious fact is that we have not here to deal with a single bone, but a large number of them, piled on top of one another. Each of these vertebræ (fig. 5) is irregular in shape, consisting of a bung-shaped *body* (centrum) and a curved *arch* from which several projections or processes grow out. The successive bodies are placed one above the other on the ventral side of the backbone, and are separated from one another by pads of gristle which act as buffers, allowing at the same time as much flexibility as is consistent with a proper degree of firmness. Successive arches are further linked together by the overlapping of their processes. It will further be noted that in this way a kind of tunnel is formed in which the spinal marrow is lodged and efficiently protected. This is essential, for it is an exceedingly delicate organ, and any severe injury inflicted upon it would result either in death or else in paralysis of the parts posterior to the damaged region. The vertebræ differ among themselves in size and shape, and are divisible into groups belonging to different regions of the body. The first seven, beginning at the head end, are the *neck-vertebræ*, and of these the first and second have a special interest (fig. 6). The first, or *atlas*, supports the rounded skull, just as, to compare

Fig 4.—Backbone

7, 19, 24, 29, 33, Last vertebræ of neck chest, loin, sacral, and tail regions, *a b*, ventral curvatures, *g g g*, pads of gristle between bodies of vertebræ

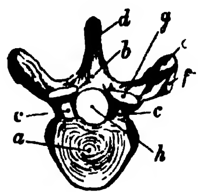


Fig 5.—A Dorsal Vertebra

a, body *b c*, arch *d g*, processes; *h*, spinal canal

small things with great, the giant Atlas was supposed to bear the globe on his shoulders. This vertebra presents two shallow cups on the side facing the skull, from which project two corresponding rounded projections. A hinge-joint is thus constituted, as a result of which we are able to nod our heads backwards and forwards. Movement from side to side would, however, be restricted by this arrangement if it were not for another one which exists to compensate it. The second vertebra, or *axis*, bears a firm bony peg, which projects through the ring-like atlas towards its ventral side and forms, as its name indicates, a pivot round which the head with the atlas can turn, too great freedom of movement being prevented by firm fibrous bands or ligaments which run from the peg to the skull. Following the neck-vertebræ come twelve rib-bearing *chest-vertebræ*, which form part of the dorsal wall of the chest-cavity. Next come five large *loin-vertebræ*, the size of which is due to the necessity for a firm support to the very considerable weight of the parts of the body coming above them. Still lower down this necessity becomes still greater, and the demand is met by a complicated basin-shaped mass of bone, the *pelvis*, the numerous arch-like curves of which are so arranged as to confer immense strength. The pelvis consists of three bones firmly fused together in the adult, the dorsal one, which alone belongs to the backbone, being the *sacrum*, made up of five broad flat sacral vertebræ immovably fused together. The last section of the backbone is a small curved structure termed the *coccyx* (Gk. for cuckoo), so named from its supposed resemblance to a cuckoo's beak, and resulting from the intimate union of four small tail vertebræ. It is chiefly interesting as being the useless representative of the tail, which is such a useful appendage in many of the lower forms.

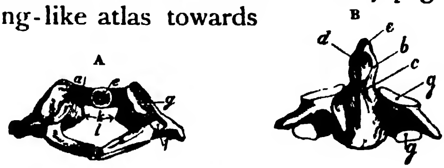


FIG. 6.—A, Atlas vertebra, anterior view, ventral surface upwards *a e*, body, *g*, cup for reception of occipital condyle, *f*, process, *k*, position of a ligament, *l*, spinal canal B, Axis vertebra, ventral view, anterior end upwards, *b e d*, parts of peg, *c*, anterior end of body, *g g*, processes.

2. *The Skull.*—The hard parts of the head together constitute the *skull* (see fig. 7), which consists of a brain-case, of relatively enormous size in Man, and the bony framework of the face. The *brain-case* is made up of a number of flat bones, firmly united by interlocking edges and also in part by overlapping surfaces, the net result being an arched box of very

great resisting power—a very necessary arrangement, since the contained brain, the most important organ in the whole body, is soft and pulpy. A further point of interest is found in the fact that the skull-bones possess three layers, a compact outer layer, a spongy middle layer, and a compact inner layer. Here again is another arrangement for breaking shocks.

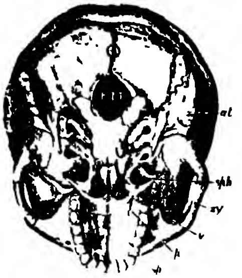


Fig. 7. Base of Skull.

F.M., Foramen magnum surrounded by occipital bone; *oc*, an occipital condyle; *p*, *sp*, bony palate with teeth in a curve round margin; *n*, opening of nasal cavities; other letters refer to various bones.

As previously stated, the spinal marrow is continuous with the brain, and this continuity is rendered possible by the presence of a round hole (*foramen magnum*) in the back of the cranium bounded by the occipital bone, which is really made up of four bones fused together (fig. 7). On each side of this hole is a smooth rounded prominence, or occipital condyle, which fits into a corresponding cup in the atlas vertebra. The presence of *two* condyles is an important point to notice from the classificatory stand-point.

The skeleton of face (fig. 7) is constituted by numerous bones arranged in a very complicated manner, and including as their largest elements the framework of the jaws. The two upper jaw bones are the biggest, and they are firmly united together in the middle line, presenting also on the side facing the mouth a curved margin carrying the sockets for the upper teeth. The lower jaw bone, or mandible, really consists of two firmly-united bones bearing the sockets for the lower teeth. It is united with the main skull by a hinge-joint, formed by two rounded projections (condyles) of the mandible, which fit into corresponding pits above. This joint varies in character in different animals in accordance with the kind of movement which the lower jaw has to execute, and this again depends upon the nature of the food and the manner of feeding. In a flesh-eating animal, such as the cat, the condyles are transversely elongated, so as to give a very perfect hinge-joint, only permitting a series of snaps. Anyone who has watched a cat or dog feeding is familiar with the kind of action indicated. A large number of familiar animals, such as rat, mouse, squirrel, and rabbit, constantly gnaw various things with their chisel-shaped front teeth, and in them the condyles are elongated from before backwards, allowing of a corresponding movement. Those forms again which

"chew the cud", *e.g.* cow, sheep, goat, are obliged to move their jaws from side to side, a kind of movement which is rendered possible by flattish condyles. In human beings the lower jaw can be moved in all three ways, and the condyles are not only convex from side to side, and from before backwards, but are set on obliquely, an arrangement which permits all varieties of movement.

The skeleton of the face is also reckoned to include another loose bone, the hyoid (so named from its resemblance to the Greek letter Ypsilon, Υ, corresponding to our U), which supports the root of the tongue, and keeps the top of the windpipe open. It possesses two pairs of horn-like projections, and is interesting as representing what is a very elaborate apparatus in such lower forms as fishes.

In the skeleton of the face there are also properly included the minute bones or ossicles which belong to the organs of hearing, and regarding which more will be said elsewhere.

3. *The Ribs*, and 4. *The Breast-bone.*—The ribs and breast-bone (sternum) complete the axial endoskeleton. These, with the thoracic part of the backbone, form a firm framework by which the heart, lungs, and other delicate structures contained in the chest are protected from injury. There are twelve pairs of ribs, jointed on to the backbone dorsally, and, except the two last pairs, connected by pieces of gristle (costal cartilages) with the breast-bone.

SKELETON OF THE LIMBS.—Turning to the skeleton of the limbs (see p. 196), we find that, both as regards the arm and leg, we can distinguish between (*a*) a firm bony girdle by which the base of the limb is connected with the trunk, and (*b*) the hard parts within the free or movable portion of the limb. In the case of the arm we have a *shoulder-girdle* consisting of two bones, the broad triangular shoulder-blade (scapula), placed dorsally and firmly bound by muscles to the trunk skeleton, and the collar-bone (clavicle), which runs across from scapula to sternum. One corner of the triangular scapula is provided with a shallow cup, the *glenoid cavity*, into which the rounded end of the upper-arm bone fits so as to form a ball-and-socket joint, which allows of very free movement. It is important to notice a bony projection which overhangs the glenoid cavity, and which, from a supposed resemblance to the beak of a raven (Gk. *kŏrax*,

a raven), has been named the *coracoid process*. Here again we have a vestige of what is an important structure elsewhere, representing as it does the coracoid bone, which, in such a creature as a bird, is as large as the scapula and quite distinct from it.

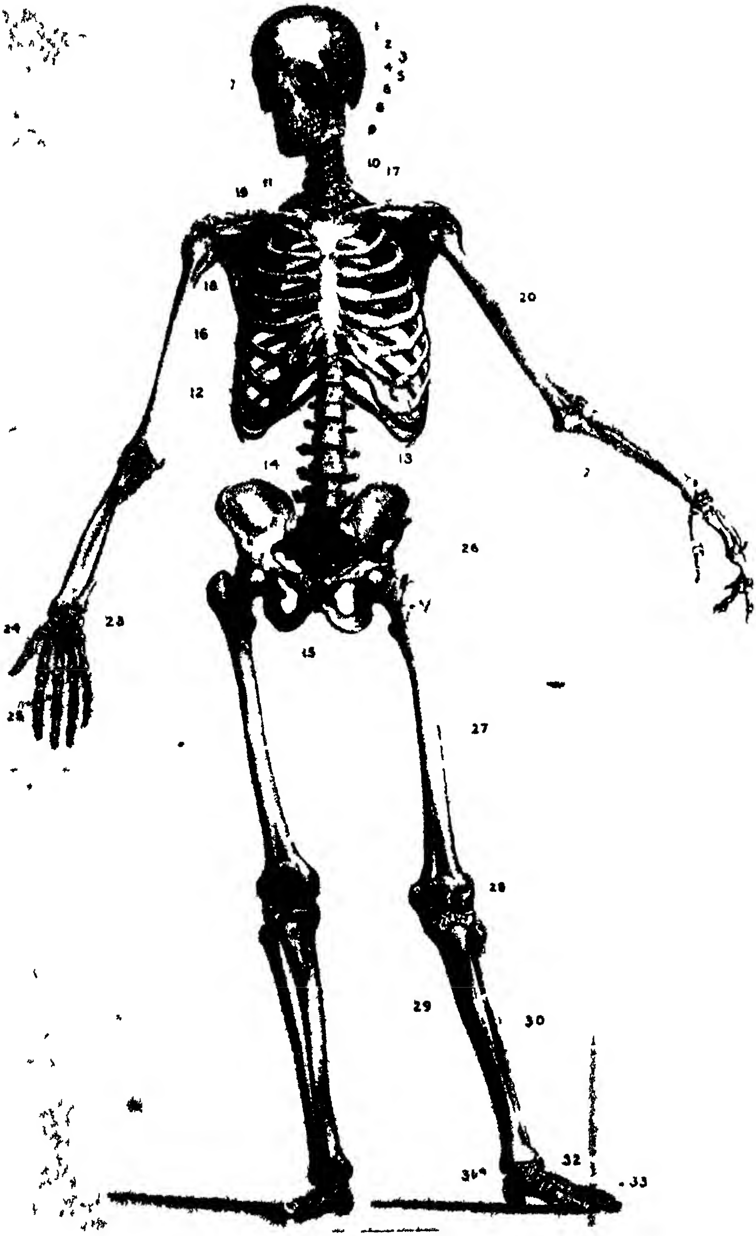
1. *Arm.*—The arm itself is supported by a number of bones, many of which belong to the class of long bones, and of which we may take the *humerus*, or upper-arm bone, as a typical example. This consists of a hollow marrow-containing shaft, and swollen extremities presenting smooth gristle-covered surfaces well adapted for entering into the formation of joints. The shaft is a good example of the mechanical device of the hollow column, presenting the advantages of lightness and economy of material without loss of strength. The thickened ends are made for the most part of spongy bone, consisting of layers arranged in such a way as to combine great strength with lightness, while at the same time the transmission of shocks is very largely hindered. As already mentioned, the upper end of the humerus helps to form the ball-and-socket-like shoulder-joint. At its lower end is a pulley-shaped surface, which, in combination with the two long bones of the forearm, gives the hinge-like character to the elbow-joint. These bones are known as the radius and ulna, the former being on the thumb-side, and the latter on the little finger side. The upper end of the ulna is large, projecting behind the elbow as what is popularly called the "funny bone", but is in reality not a separate bone at all. The lower end of the ulna is comparatively small. Exactly the reverse is true of the radius, which is small at its upper end, but large at its lower end, where it has to support the hand. And here we find a point of great interest. The forearm is capable, as is known to everyone, of a rotatory movement whereby the hand can be turned with its back upwards, the position of *pronation*, as contrasted with the position of *supination*, in which the palm is upwards. In the latter position the ulna and radius are parallel, but in the former the radius, carrying with it the hand, crosses obliquely over the ulna. Such an arrangement obviously adds vastly to the use of the hand and arm, and is absent in those animals where the fore-limbs are used mainly for locomotor purposes.

The *wrist* is supported by eight small irregular bones, arranged so as to combine strength with flexibility, as well as to break the shocks to which the hand is especially liable. They are succeeded

THE HUMAN SKELETON

1. Parietal bone.
2. Frontal bone.
3. Temporal bone.
4. Orbit.
5. Side of occipital bone.
6. Malar, or cheek-bone.
7. Nasal bone.
8. Upper jaw-bone.
9. Lower jaw.
10. Four lower neck (cervical) Vertebræ.
11. Two upper chest (thoracic) Vertebræ
12. Two lowest chest (thoracic) Vertebræ
13. Loin (lumbar) Vertebræ.
14. Sacrum.
15. Coccyx.
16. Ribs.
17. Breast-bone (Sternum).
18. Shoulder-blade (Scapula) } Shoulder Girdle.
19. Collar-bone (Clavicle) } Shoulder Girdle.
20. Humerus.
21. Radius.
22. Ulna.
23. Wrist-bones (Carpus).
24. Palm-bones (Metacarpus).
25. Finger-bones (Phalanges).
26. Hip-bones, Hip Girdle.
27. Thigh-bone (Femur).
28. Knee cap (Patella).
29. Shin-bone (Tibia).
30. Clasp bone (Fibula).
31. Ankle-bones (Tarsus).
32. Instep bones (Metatarsus)
33. Toe-bones (Phalanges).

2



THE HUMAN SKELETON

by five elongated bones, which support the palm, and from their shape are classed with the long bones. Fourteen small phalanges of similar shape complete the skeleton of *the hand*, each finger possessing three, while the thumb has only two. Each end-phalanx is broadened out and roughened at its tip to afford a support to a nail.

Two further points of interest deserve mention in regard to the hand. One is the unequal lengths of the *digits* (or fingers), a device which renders them much more efficient in delicate manipulations, enabling their tips to be brought together with great ease. The other point is the opposability of the thumb, *i.e.* it can be bent over so as to directly oppose any one of the fingers. How important a matter this is may be realized by trying to pick up a small object, say a pin, by means of the fingers alone. The arrangement is rendered possible by the peculiar nature of the joint between the base of the thumb and the wrist. The opposing surfaces are here saddle-shaped, allowing a much larger range of movement than any other combination of curves. The same kind of jointing is found in a bird's neck, which is well known to be exceedingly flexible.

2. *The Leg.*—Here we find in the first place a *hip-girdle*, comparable to the shoulder-girdle of the upper limb. But the necessity for supporting the very considerable weight of the body has in this case brought about an intimate union with the skeleton of the trunk, and the two girdles are firmly united with one another and with the *sacrum* to form the basin-like *pelvis* mentioned above (see p. 27) Each girdle is constituted by an irregular hip-bone, consisting of three elements fused together, and corresponding to what in many animals are clearly to be distinguished as three separate bones. The pelvis is arched so as the better to support the weight of the body transmitted to it, and thence to the thigh-bones, by means of the sacrum, which may be compared to the keystone of the arch. A further use of the pelvis is to protect certain delicate internal organs placed within its cavity.

On the outer side of each hip-bone is a deep cup for receiving the globular upper end of the large *femur*, or thigh-bone, which is comparable to the humerus in the upper arm. The joint at the thigh, like that at the shoulder, is of the ball-and-socket kind, but here greater firmness is necessary, and consequently less

freedom of movement is permitted, the cup being much deeper and the union by fibrous bands more intimate.

The lower end of the femur helps to form the hinge-like knee-joint in conjunction with the shin-bone (*tibia*) of the lower leg, which corresponds to the radius in the forearm. The front of this joint is protected by a round and somewhat flattened bone, the *patella* or knee-pan. There is nothing corresponding to this in the elbow.

The chief bone of the lower leg is the *tibia*; but there is also a second much slenderer one, the *fibula*, corresponding to the ulna in the forearm, but not helping to form the knee-joint. Just as the wrist is supported by a number of irregular bones, so is the *ankle*, but as these have to support the weight of the body they are relatively much larger and stronger. Following them come five sole-bones, corresponding to palm-bones; while the toes, like the fingers, are completed by fourteen phalanges, which, however, are relatively short. The great toe is not opposable and is very much larger than the others, since it plays an important share in supporting the weight of the body. It may be remarked that the skeleton of the foot presents an arch from before backwards, and another from side to side, an arrangement which combines great strength with a large amount of springiness. The weight of the body falls mainly on the heel, toes, and outer side of the foot

NUTRITION.

The body is constantly undergoing waste, and also, in the earlier part of life, increasing in volume, or growing. This waste must be counterbalanced and materials for growth provided: hence the necessity for food, which may be compared to the materials used for repairing a machine and, it may be, making additions to it. And just as the original nature of a machine determines the material to be employed, so also in the case of the body. In other words, if we are to understand the nature of the food, we must have some knowledge of the composition of the body.

Chemical Composition of the Body.—When the body of an animal is acted upon by intense heat most of it is dissipated in the form of gas, the comparatively small remainder, or ash, consisting of various mineral matters. The gaseous portion, when

further analysed, is found to contain the four elements, Carbon, Hydrogen, Oxygen, and Nitrogen. It is therefore to be expected that our food should consist in the main of compounds of the same four chemical elements[1], and this is actually the case. Obviously this must be so for the fleshy part of the food, and it is also true for the vegetable portion. The different kinds of food may be classified as follows:—

1. *Nitrogenous Food*, consisting, in ultimate analysis, of carbon, hydrogen, oxygen, and nitrogen, together with sulphur, and in some cases phosphorus. Such foods are of exceedingly complex chemical nature, and may broadly be called *proteids* or *albuminoids*[2]. The last name is taken from albumin, of which white of egg may be considered as a type; while egg-yolk, lean meat, blood, gelatin, and cheese are of the same nature in whole or part. An example from the vegetable kingdom is gluten, the sticky constituent of flour, to which the tenacious character of dough is chiefly due.

2. *Non-nitrogenous Food*, as the name indicates, contains no nitrogen. Its various kinds are:—

(*a*) *Carbohydrates*, containing carbon, hydrogen, and oxygen, and including starch, sugar, gum, &c.

(*b*) *Hydrocarbons*, or fats and oils, consisting of the same three elements, arranged, however, in different proportions.

(*c*) *Mineral Salts*, including compounds of lime and iron, as well as common salt (sodium chloride). The more complicated foods enumerated under the preceding headings contain a varying amount of such mineral compounds, which have, however, to be supplemented in Man and various other animals by common salt. The importance of salts of lime becomes apparent when we remember that the hard part of bones and teeth consists of them.

(*d*) *Water*, consisting of hydrogen and oxygen, and generally containing mineral salts dissolved in it. Water is not only taken in the form of drink, but also forms an important constituent of albuminous, starchy, and fatty foods.

This complex food, unlike the food of plants, which is entirely gaseous or liquid, is largely taken into the body in the form of

[1] A chemical element is a substance which cannot, so far as we know, be resolved into components of different nature.

[2] The term *albuminoid* is often used in a narrower sense than this.

solid or semi-solid fragments, hence the necessity for an internal digestive cavity, the possession of which is characteristic of a higher animal as contrasted with a higher plant. In Man, for example, we have a set of digestive organs, the function of which is to deal with this crude food and reduce it to such a condition that it can be utilized for repair and growth, or, in other words, to digest it.

Digestive Organs.—These consist essentially of a long digestive tube, more briefly termed the gut, into which a number of structures known as digestive glands pour fluids.

1. *The Gut*.—The gut (figs. 8 and 9) is of very unequal width in different parts of its course, and, being very much longer than the body, is only able to pursue a straight course from the mouth

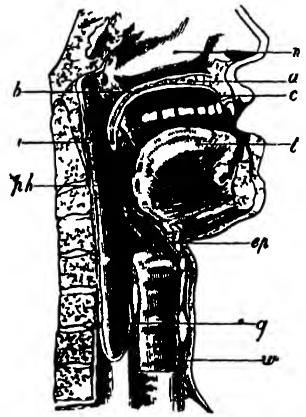


Fig. 8.—Section showing Mouth and Nasal Cavities, Gullet, Windpipe, &c.

a, Hard palate; *b* to *u*, soft palate; *c*, mucous membrane; *n*, cavity of nose; *t*, tongue; *ph*, pharynx; *g*, gullet; *ep*, epiglottis; *w*, windpipe.

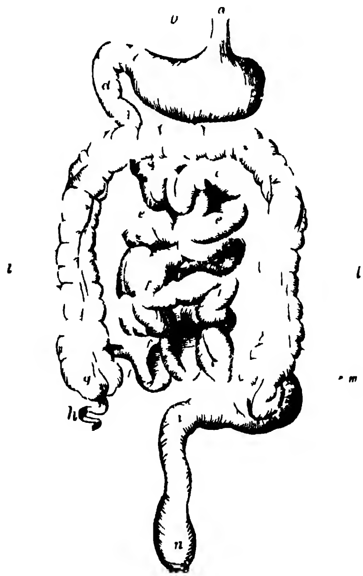


Fig. 9.—The Gut.

a, Gullet; *bc*, stomach; *def*, small intestine; remaining letters indicate parts of large intestine.

to the end of the thorax, while in the abdomen it is largely coiled. The mouth, bounded by fleshy lips, leads into the fairly large mouth-cavity, marked features of which are the teeth and muscular tongue. At the back of this cavity is the pharynx, communicating with the cavities of the nose and ear; while on its floor is an opening, the glottis, leading into the breathing organs. The pharynx may be looked upon as the dilated front

end of a narrow muscular tube, the gullet, which succeeds it, and, running along the neck and through the thorax, pierces the midriff, to become continuous with the large transversely-placed stomach, which has thick muscular walls. This in its turn is succeeded by a very long thin-walled tube, the small intestine, followed by a shorter but broader large intestine, which ultimately opens to the exterior.

The whole of the gut is lined by the mucous membrane, a soft reddish skin richly provided with blood-vessels.

2. *The Teeth* (figs. 10 and 11).– These deserve further mention, as they present interesting adaptations to the food and mode of feeding, while their number and form furnish important characters for purposes of classification.

All the teeth are imbedded in sockets, the imbedded part being the fang, while the projecting portion constitutes the

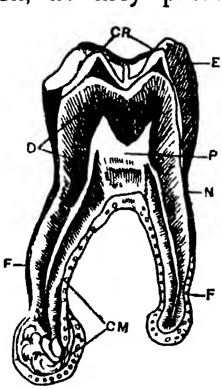


Fig. 10 Section of a Tooth
Cr, Crown, N, neck FF, fangs P, pulp cavity E, enamel D, dentine Cm, cement

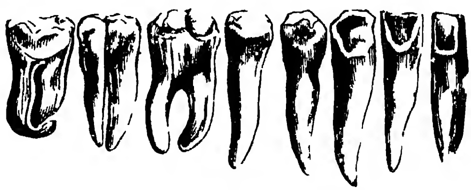


Fig 11 Kinds of Teeth
This figure shows the eight teeth in one half of a jaw

crown. The greater part of a human tooth is composed of a very hard substance, dentine, within which is hollowed out a cavity for the sensitive pulp, richly provided with blood-vessels and nerves. The fang is covered by a layer of bony material, cement, while the crown is invested by an intensely hard substance, the enamel. It is a matter of common knowledge that there are two sets of teeth, the first or milk set consisting of twenty teeth, which are replaced by the thirty-two teeth making up the permanent set. Beginning with the latter, we find in the front of the jaws eight chisel-edged incisors adapted for dividing food. Outside these are the four pointed eye-teeth or canines, which in such creatures as cats and dogs play an important part as weapons and holdfasts. Lastly come the

broad-crowned cheek-teeth, twenty in number, of which the first eight are known as bicuspids or premolars, while the remainder are called molars. All this may be expressed by a dental formula as follows:—

$$i. = \frac{2\ \ 2}{2\ \ 2},\quad c. = \frac{1-1}{1-1},\quad p.m. = \frac{2-2}{2-2},\quad m. = \frac{3-3}{3-3} = 32.$$

[*i.* = incisor, *c.* = canine, *p.m.* = premolar, *m.* = molar.]

Each fraction corresponds to one kind of teeth, the numerator representing upper and the denominator lower ones, while the dashes above and below mark the distinction between teeth on the right and left side. Since these structures are symmetrically arranged it is only necessary to represent those of one side, and so it is convenient to shorten the formula to—

$$\frac{2\ .\ 1\ .\ 2\ .\ 3}{2\ .\ 1\ .\ 2\ .\ 3} \times 2 = 32.$$

In the first or milk set the incisors, canines, and premolars are represented respectively by milk incisors, milk canines, and milk molars, while the molars of the permanent set have no predecessors.

Fig. 12.—The Salivary Glands.
p, p′, parotid; *sm*, sub-maxillary; *d* is placed below the duct of the parotid.

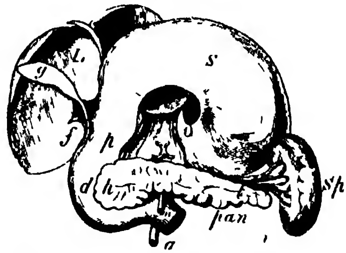


Fig. 13.—Relations of the Stomach to the Liver, Pancreas, and Spleen.
s, Stomach; *d*, small intestine; *l*, liver; *g*, gall-bladder, placed to left of bile-duct *h*; *p*, pancreas; *sp*, spleen; *v*, placed below blood vessels of spleen; *a* and *v*, blood vessels.

3. *Digestive Glands* (figs. 12 and 13).—These elaborate or secrete different fluids, which act chemically upon the food. Opening into the mouth-cavity are three pairs of soft masses, the *salivary glands*, which secrete the spittle or saliva. One pair is placed in front of the ear (parotid), and it is these structures which swell up and become painful in cases of mumps. A second pair (sub-maxillary) are placed between the halves of the lower jaw, while the third and much smaller pair (sub-lingual) are imbedded in the deeper part of the tongue.

Other very important organs of the kind, the *peptic* or *gastric glands*, are found as innumerable minute branching tubes opening into the stomach, in the lining of which they are imbedded. The fluid secreted by these glands is the gastric juice.

The *liver*, which is the largest organ of the body, is, among other things, a digestive gland. It is a bulky reddish-brown mass placed in the upper part of the abdominal cavity, and its secretion, the bile or gall, passes into the beginning of the small intestine through a small thick-walled tube, the bile-duct. Connected with this is a pear-shaped bag, the gall-bladder, in which bile can be temporarily stored up.

The last digestive gland of importance is the *pancreas*, popularly known as the sweetbread, which lies in the first loop made by the small intestine, and pours its secretion, the pancreatic juice, through a short tube into the bile-duct.

PROCESS OF DIGESTION.—The process of *Digestion* essentially consists in the conversion of food into a dissolved or else a very finely-divided state. It is effected partly in a *mechanical*, partly in a *chemical* manner.

1. *Mechanical Digestion.*—As regards mechanical digestion an important part is played by the teeth, which reduce the food to small fragments, this being rendered more easy by the pouring out of saliva, which acts as a moistening and softening agent. The muscular tongue and cheeks are also of importance here, because they help to keep the fragments between the grinding teeth. In gullet, stomach, and intestines a further division is brought about as the result of a squeezing action exerted by the muscle-containing walls of these organs.

2. *Chemical digestion* is even more important. Within the stomach abundant gastric juice is poured on to the digesting food and acts more particularly upon the albuminoids, converting some of them into a soluble form known as peptone.

The *saliva* is concerned with starchy foods, which it converts into a kind of sugar.

Chemical digestion is completed in the small intestine by the *bile* and *pancreatic juice.* The latter finishes the work on the starchy and albuminous matters begun by saliva and gastric juice, besides which it acts on fats, converting them into a milky state or emulsion, where minute globules of the fat are suspended in fluid. The bile helps in the digestion of fats, and is of importance in

several other ways, *e.g.* it prevents the digesting food from becoming putrid.

The digested foods are now absorbed into the minute blood-vessels which branch in the mucous membrane, the digested fats, however, passing into other minute tubes called lacteals, which ultimately communicate with the blood-system. It must, of course, be understood that blood-vessels and lacteals do not open into the cavity of the gut, but the digested materials, so to speak, soak into them. Those parts of the food which are not digested pass out of the body altogether.

CIRCULATORY ORGANS

Branching elaborately within the body, and sending its twigs into almost all its different parts, is a closed set of tubes constituting the blood-system. Propelled by the heart or central pump the red fluid known as blood is constantly circulated through this system. Supplementary to the blood-system we have a set of spaces and tubes (of which the lacteals mentioned above form a part) making up the lymph-system. This contains a pale fluid, the lymph, which it pours into certain of the great blood-tubes. The two fluids, blood and lymph, especially the former, may be regarded as a sort of medium of exchange as regards the various parts of the body. Certain things are taken out of them to meet local requirements, and certain other things pass into them.

Speaking more precisely, the functions of the circulatory system are as follows: (1) It distributes the digested food, *i.e.* the materials for repairing waste and providing for growth; (2) It removes waste matters from all parts of the body, and carries these to organs which can get rid of them; (3) It carries oxygen to promote this waste; and (4) It distributes heat and equalizes the temperature of different parts.

The Blood (figs. 14 and 15).—When examined under the compound microscope a drop of blood is found to consist of colourless liquid (plasma) in which float a vast number of minute bodies, the *blood-corpuscles.* These are of two kinds—red, and colourless or white. The former are biconcave discs not more than $^1/_{3200}$ of an inch in diameter, and they owe their colour to the presence of a peculiar pigment (hæmoglobin) that, as we shall presently see, is of great importance in respiration. The white or colourless

corpuscles are less numerous but somewhat larger ($^1/_{2300}$ of an inch in diameter), and possess the power of spontaneous movement by thrusting out lobes of the semi-fluid substance (protoplasm) which composes them. They are thus enabled to slowly crawl, as it were, along the walls of the blood-vessels. In the middle of each such colourless corpuscle is a particle of somewhat different chemical nature, the nucleus, and this is probably to be regarded as a modification of the substance composing the rest of the corpuscle. No such particle can be discerned in a human red corpuscle, which is therefore said to be non-nucleated, a character which happens to be one of classificatory importance.

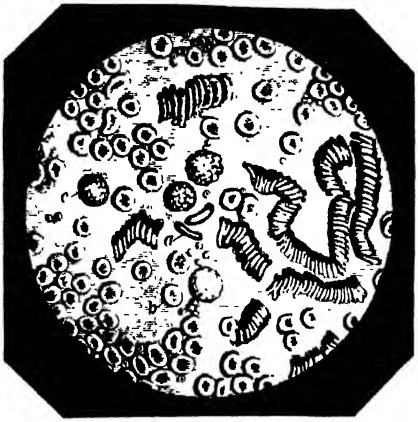


Fig 14 - A Drop of Blood, seen under a microscope magnifying by 350 diameters
a and *b*, red corpuscles *c*, white corpuscle

Fig 15 - White Blood Corpuscle Its successive changes of shape

THE HEART AND BLOOD-SYSTEM.—This very complicated organ is in principle a force-pump possessing an internal set of valves which only permit fluid to pass in certain directions. The blood-vessels which carry blood to it are veins, while those which carry it away are arteries. To understand the heart's action it is necessary to consider the simplest case, that of a heart with only one chamber or cavity (fig. 16). We may represent such a heart by an india-rubber syringe with a tube at each end, one for carrying fluid in and the other for carrying it out. There must also be, at least at one end, an internal valve consisting of a flap which readily permits fluid to pass in one direction but resists its passage in the other. In such a simple model the central swelling will represent the heart, while the tube conveying fluid into it will play the part of a vein, and the other tube the part of an artery. Propulsion of fluid will be

brought about by squeezing with the hand. An actual heart requires, of course, no squeezing from outside, its walls moving in such a way that the internal cavity is alternately diminished and increased in size. This is due to the fact that its substance is made up of slender muscular fibres arranged in a very complicated fashion. Each fibre possesses the power of contraction, *i.e.* it is able to shorten itself, becoming at the same time thicker. It is clear, therefore, that if a large number of such fibres arranged transversely and obliquely to make up the wall of a hollow structure contract at the same time, the result will be that the contained cavity becomes smaller, regaining its original size when the fibres again relax. This is what happens in the case of a heart, enabling it to do pumping work.

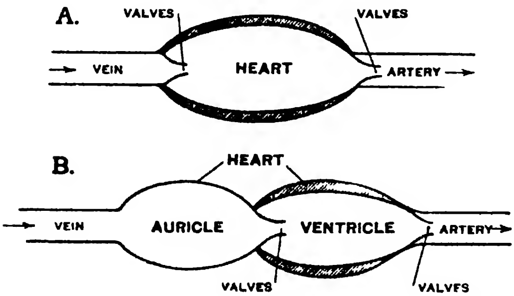


Fig 16.—Diagrammatic Hearts A, One chambered, B, two-chambered

An advance upon the simple one-chambered heart as just described is found in such a case as the common garden snail, where there are two chambers (fig. 16), one a thin-walled *auricle*, receiving blood from the vein, and squeezing it on into a thick-walled *ventricle*, which does the pumping work.

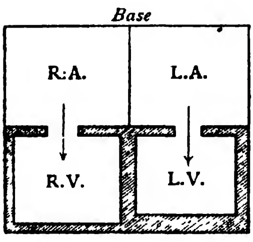


Fig. 17.—Diagram of Auricles and Ventricles

R A and L A, Right and left auricles. R V and L V, right and left ventricles.

The heart of a human being, however, has two sets of pumping work to do—(1) it forces pure blood all over the body, and (2) it drives impure blood to the lungs for purification. It is therefore not surprising that in such a heart there are four chambers, right and left auricles, and right and left ventricles, disposed as shown in the accompanying diagram (fig. 17). The right side of the heart contains only impure blood which it receives from the great veins, which open into the right auricle. This chamber passes the blood on to the right ventricle, which pumps it through a large vessel (pulmonary artery) to the lungs. These purify the blood, and from them it is conducted through pulmonary veins to the left

auricle, from which it enters the left ventricle in order to be pumped through a great artery to the body at large. This artery is known as the *aorta* (Gk. *aĕirō*, I carry), and it is characteristic for the group of animals to which Man belongs, *i.e.* the Mammalia, that the curved part or arch with which the aorta begins should turn to the left. In a Bird it would be found curving round to the right.

If the *aorta* be traced, its arch will be found to give off large branches to the anterior part of the body, after which it bends into the middle line, and (as the dorsal aorta) runs just ventral to the backbone, supplying the parts it passes, and ending posteriorly by forking into two great vessels for the lower limbs. Any branch artery farther traced will be found to divide, tree-like, into smaller and smaller twigs, which at last pass into a close net-work of excessively minute thin-walled tubes, the *capillaries.* The same thing will be observed on tracing the pulmonary artery. It may, in fact be said that almost all parts of the body are traversed by a dense net-work of capillaries, and from these the smallest veins arise, uniting, river-like, into larger and larger trunks till the great veins opening into the heart are constituted. We may therefore say that the heart and blood-vessels form a closed set of tubes, as the capillaries intervene between the smallest arteries and the smallest veins. This may be clearly seen in the web of a frog's foot.

Capillaries are of enormous importance, because their thin walls permit exchanges between the blood they contain and the body-substance they traverse.

The veins of the stomach, intestine, and certain other parts unite into a large portal vein, which enters *the liver*, and there divides up into smaller and smaller branches. The blood in this vein contains most of the digested food which has been absorbed from the gut, and the object of passing it through the liver is to let that organ take up some of these products, and store them for distribution as needed. The impure blood from the liver itself is poured by several blood-vessels into one of the great veins running to the right auricle. The arrangement just described for supplying the liver with impure blood, in addition to the pure blood which it gets from a branch of the aorta, is called the portal circulation.

THE LYMPH-SYSTEM.—The circulatory organs include a *lymph-system* as well as a blood-system. The *lymph* is a clear,

colourless fluid, consisting of plasma and colourless corpuscles. It is contained in the large internal cavities of the body, in minute crevices which exist in the substance of the various organs, and in delicate *lymphatic vessels* which ramify in most

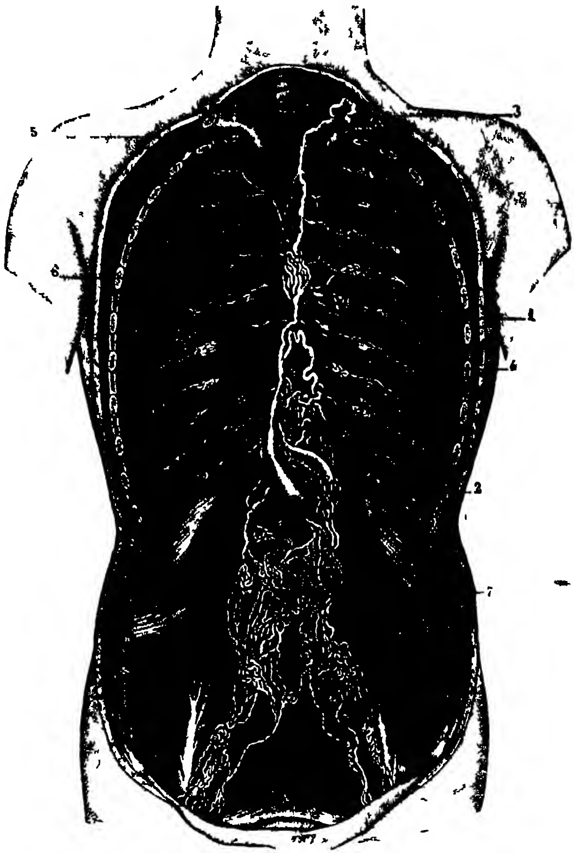


Fig 18 —The Thoracic Duct and Lymphatic Vessels 3 1 2 The duct, opening into great veins at 3.

parts of the body. Those of the intestines are termed *lacteals*, and receive the digested fats. Most of the lymphatics ultimately open into the thoracic duct (fig. 18), a narrow tube lying ventral to the backbone, and opening on the left-hand side into the great veins at the base of the neck. In this way the blood receives the digested fats, and a constant supply of colourless corpuscles.

The so-called *ductless glands* are related to the lymph-system. The largest of them is the dark-red milt or *spleen* (fig. 13), situated close to the stomach. It has to do with the destruction of worn-out red corpuscles. The *thyroid gland* is closely applied to the ventral side of the larynx, and is notorious as the organ which swells up in cases of Derbyshire neck (goître). It has been proved to be of importance in regulating the nutrition of the body. The *thymus gland* is a fatty-looking mass wrapped round the base of the heart, and much larger in infants than in adults. In the early stages of life it is one of the chief sources of colourless corpuscles.

Lymphatic glands are little swellings placed here and there in the course of lymphatics (fig. 19). New colourless corpuscles are constantly being formed in them.

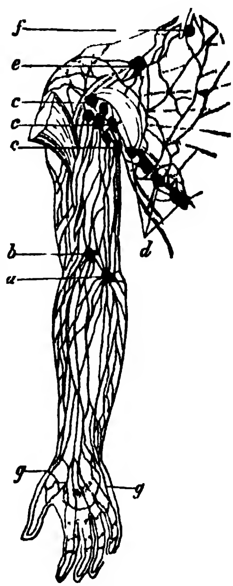


Fig. 19.—Lymphatics of the Arm and Arm-pit.

Glands at the inner side of the elbow, *a b*; in the arm-pit, *c c c*; on the chest in front of the arm-pit, *d*; above the collar-bone and communicating with the arm-pit, *e f*; *g g* point to lymphatic vessels forming an arch round the hand. The dark lines are lymphatic vessels.

WASTE-REMOVING ORGANS

The living substance making up the body of an animal is constantly undergoing a process of change, whereby it breaks down into simpler compounds. We have, in fact, two sets of chemical changes constantly going on within the body:—

(*a*) A series of upbuilding or constructive processes whereby the food is gradually converted, step by step, into the substances which constitute the body, and of which the most complex is the living material known as protoplasm. This series of chemical changes is comprised under the head of *assimilation* (L. *adsimilo*, I make like), *i.e.* processes whereby the body makes the material taken in as food into fresh substance like itself. Assimilation is most naturally dealt with under the head of Nutrition.

(*b*) The other set of chemical changes within the body are destructive in nature, involving the down-breaking of material, partly of protoplasm itself, and partly of other less complex compounds. These changes have been called "local death", and

are absolutely essential to life, for without them life would be impossible. Every manifestation of vitality by an organism, such as movement, production of digestive or other secretions, sensations, and mental operations, involve the breaking down or waste of material, without which the necessary energy would not be available. Broadly speaking, energy is the power of doing work, and a distinction is drawn between potential or stored energy and actual or kinetic energy. Complex chemical substances, such as high explosives, represent a store of energy, and when these break down into simpler substances, *i.e.* explode, a large amount of actual energy is liberated, which, in the case of the explosives alluded to,

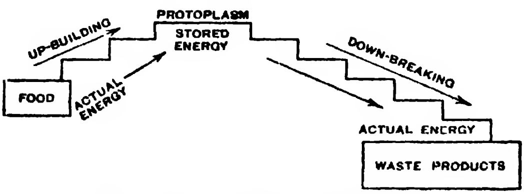


Fig. 20.—Diagram of chemical changes in Body

can be made to do various kinds of useful work. Protoplasm and the other complex body-substances are, so to speak, of explosive nature. The final results of these down-breaking changes are waste products, which have to be eliminated or excreted from the system. The accompanying diagram (fig. 20) illustrates the matter. It represents a double staircase, with a shorter ascending stair on the left, and a longer descending stair on the right. Food is represented as being on the level of the lowest step of the left-hand stair, the successive steps of which represent the stages by which more and more complex substances are built, till the most complex of all, protoplasm, is produced. The breaking down of this into simpler and simpler substances is represented by the successive steps of the descending stair, at the bottom of which are the waste products. These are represented at a lower level than the food, because they are of simpler chemical constitution. They are mainly—water (H_2O), carbonic acid gas (CO_2), and compounds of nitrogen.

The organs which get rid of waste are (1) skin, (2) lungs, (3) kidneys, and (4) liver.

1. The Skin, among its other functions, eliminates a large amount of water and small quantities of the other kinds of waste, here constituting the excretion called sweat or perspiration. Imbedded in it are innumerable sweat-glands, in the form of

minute coiled tubes, each opening by a very small pore on the surface. The coiled part of each such gland is sunk deeply in the dermis, and is surrounded by capillary blood-vessels, from the blood contained in which the materials making up sweat are separated.

2. The Lungs (fig. 21) are two spongy bodies contained in the thorax, and their function as breathing or respiratory organs is twofold—(1) to excrete or get rid of the waste carbonic acid gas, together with a large quantity of water, and (2) to supply the blood with free oxygen, which is necessary as the agent by which the waste constantly going on in the body is rendered possible. This waste is in fact a process of oxidation, *i.e.* a conversion of protoplasm, &c., into simpler bodies containing a larger proportion of oxygen. The lungs are spongy in character because they are made up of innumerable little air-tubes, ending blindly in groups of minute air-sacs, with walls invested by a close network of capillaries, the blood contained in which is so near to the air in the air-cells that an exchange of materials is possible. On the one hand, a large amount of the carbonic acid gas with which the impure blood is highly charged is able to diffuse into the air-sacs, from which, on the other hand, the oxygen of the air is able to diffuse into the blood. The *hæmoglobin* of the red corpuscles plays an important part as an oxygen-carrier, taking it up from the air in the lungs and readily parting with it to the substance of the body. A large amount of water in the form of vapour also diffuses out of the blood into the air-sacs. As a result of this, the air breathed out contains far more carbonic acid gas and water-vapour, but much less oxygen, than the air breathed in. This exchange of gases constitutes the essential part of breathing; but the mechanical part has also to be considered, *i.e.* the arrangements by which the air-passages of the lungs

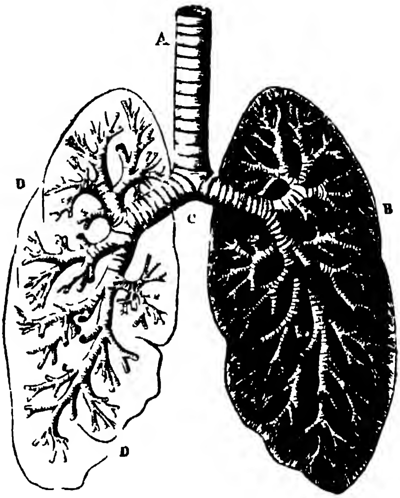


Fig. 21.—Lungs and Air-passages.
A, Windpipe, BC, bronchi, DD, smaller air passages.

are continually provided with fresh pure air, and get rid of impure air. Without going into unnecessary detail, it may be pointed out that the walls of the chest are movable, so that the size of that region is alternately increased (when air is breathed in) and diminished (when air is breathed out). During the former process, the breast-bone and ribs are moved on the joints by which the latter are hinged to the backbone, in such a way as to increase the volume of the chest from side to side and from front to back. The general nature of these movements can be easily noted by the reader in himself. At the same time the muscular midriff or diaphragm, which separates the chest from the abdomen, and in a state of rest is convex towards the former, flattens out as a result of its own contraction, and thus increases the size of the chest in the direction of its length. As the thorax is, so to speak, an air-tight box, the contained lungs are obliged to expand as it increases in volume, the result being that air passes into their larger air-passages. The reverse process to the one described, whereby diminution of volume is effected, is largely due to the elasticity of the thoracic walls, while at the time the diaphragm ceases to contract, and resumes its normal curved shape. Air consequently passes out from the larger air-passages. Purification of the air contained in the smaller air-passages (bronchial tubes) and their blind endings is brought about by diffusion. A few words are necessary on the direction taken by the air. The proper course for this (fig. 8) is through the nostrils, into the nasal cavities, and thence by a special aperture (posterior nares) into the pharynx, on the floor of which is a slit-like opening, the glottis, leading into the windpipe. Of course breathing can also be effected through the mouth, but the primary use of this is as a food-passage.

In front of the glottis there is an elastic flap, the *epiglottis* (fig. 8), which, when food is swallowed, folds back over the glottis and forms a sort of bridge to the gullet. The windpipe (trachea), into which the glottis leads, is a good-sized tube (fig. 22), with its walls stiffened by hoop-like pieces of gristle and so prevented from collapse. It can easily be felt in the front of the neck, from which it runs into the thorax, there bifurcating into a bronchus for each of the lungs. Either bronchus when traced is found to divide repeatedly to form smaller and smaller air-passages, the smallest of which end, as

already described, in delicate air-sacs. The advantage of this arrangement is to provide a very large surface over which the blood can be purified without taking up a large amount of room.

It is interesting to notice that the lungs are developed as outgrowths from the pharynx, which are at first simple pouches, but gradually become more complicated.

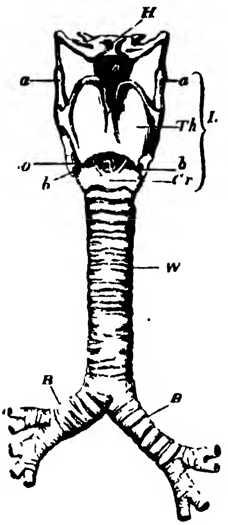


Fig. 22.—The Larynx and Windpipe

L, Larynx, formed of *Th* and *Cr*, thyroid and cricoid cartilages, *a a b b*, parts of thyroid, H, hyoid bone, *e*, epiglottis, W, windpipe; B B, bronchi.

The *organ of voice* falls to be mentioned here, since it is intimately associated with the air-passages. The beginning of the windpipe is dilated into a voice-box or *larynx* (fig. 22), supported by various pieces of gristle, of which the largest (thyroid cartilage) can be felt in the swelling known as "Adam's apple". Projecting into the cavity of the larynx are two narrow elastic cushions with sharp edges, which can be brought parallel to one another by appropriate muscles. If, when this has been done, air is sharply breathed in or out, a musical note results, and the cushions in question, commonly but rather inappropriately called the *vocal chords*, can be stretched to different extents, so that the resulting note varies in pitch, a low note being produced when they are slackened, and the opposite when they are pulled tight. Vowel sounds of various kinds are produced by altering the shape of the mouth-cavity through which the air breathed out is passed, while consonants result from momentarily blocking the air-current in different ways. The entire mechanism is extremely complicated, and this is not the place to describe it more fully.

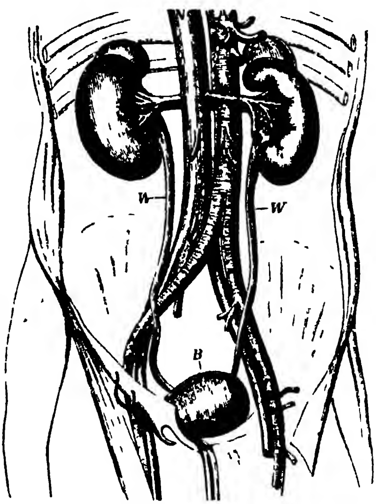


Fig. 23.—The Situation of the Kidneys

A, Dorsal aorta, V, vena cava B, bladder, W, ureters Branches of the aorta are seen going to the kidney, and veins from it are shown joining the vena cava.

3. THE KIDNEYS.—The kidneys are generally described as the excretory organs *par excellence*, the useless matter here being nitrogenous waste and mineral salts dissolved in a large bulk of water. They are two characteristically-shaped structures placed in the abdominal cavity (fig. 23) close to the ventral

side of the backbone, and from each of them a tube, the ureter, conducts the products of waste to a good-sized bag, the urinary bladder, which is sheltered in the cavity of the pelvis and opens to the exterior.

4. THE LIVER.—Nitrogenous waste is got rid of chiefly by the liver and kidneys. The liver, which has already been described as a digestive gland, is also a waste-eliminating organ, for bile is a waste product as well as a digestive juice.

ORGANS OF MOVEMENT.

1. MUSCULAR ACTION.—The obvious movements of the body are brought about by the masses of flesh technically known as *muscles*, which make up a large proportion of its weight. These muscles are of various shapes, in accordance with the differences in their uses; but they all agree in being composed of vast numbers of microscopic fibres which, under the control of the nerves, are able to contract, *i.e.* to shorten, while at the same time they become broader. The result is, that the parts to which the ends of an elongated muscle are fixed are brought nearer together. Such a muscle is generally attached at one end (the origin) to a relatively fixed part, and at the other (the insertion) to a relatively movable part. This is the case, for example, with the biceps muscle, easily felt as a mass of flesh on the front of the forearm (fig. 24). This takes origin from the scapula and is inserted into the radius, the result being that when it contracts, the forearm, being the relatively movable part, is drawn up.

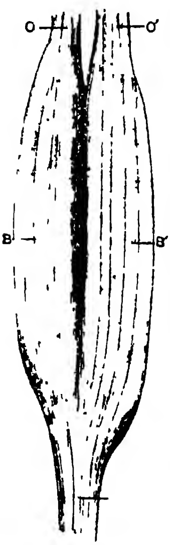


Fig. 24.—Biceps Muscle of the Arm. BB', Fleshy part; oo', origin; i, insertion.

Muscles are commonly attached by means of firm fibrous cords, the *tendons*, an arrangement which permits a large number of muscles to be attached to a small part, such as a finger-bone, and further permits such muscles to act from a considerable distance. The use of skeletal parts in giving attachment to muscles is obvious, and the numerous ridges and projections seen on bones are largely related to this function.

Muscle is also important in relation to the movements of

internal organs, as has already been seen in the case of the heart. It also enters into the walls of the blood-vessels, serving to regulate their size, and the walls of the food-tube are also largely composed of the same substance, which here exerts a kind of squeezing action by which the digesting food is gradually passed on. The muscle, however, making up the flesh of the body is different in structure from that found in internal organs, and is termed voluntary, being under the direct control of the will; while the muscle of the heart, &c., is involuntary, because it cannot be regulated in this way.

2. Ciliary Action.—Movement in the human body is, however, not all due to muscular action, but can be brought about in two other ways. One of these is *ciliary action*, of which a good example is afforded by the lining of the windpipe. If this is examined under a compound microscope it will be found to be lined with fragments of protoplasm (cells), covered thickly with short protoplasmic threads known as *cilia* (fig. 25). Each cilium is able to alternately bend and straighten itself, and when numerous cilia work together, as is usually the case, they are able to move along small particles placed upon the surface they beset. Their action in the case mentioned is to sweep particles of dust, &c., towards the exterior, thus keeping the ciliated surface clean. The last kind of movement is the peculiar creeping motion exemplified by the colourless corpuscles of blood and lymph (fig. 15). It is said to be *amœboid.*

Fig 25.—Cells of Ciliated Epithelium, much magnified

The two kinds of movement just described are much more primitive than muscular action, and, as might be expected, play a much more leading part in the lower forms of life than they do in such a complicated organism as a human being.

NERVOUS SYSTEM AND SENSE ORGANS.

The great complexity of the body, with its numerous subtly interwoven functions, demands some means of controlling and correlating these, and of keeping the body as a whole in touch with the outer world. The means is found in those organs to which the terms nervous system and sense organs are applied.

The Nervous System.—The nervous system essentially consists of certain central organs, which may be regarded as

the head-quarters of the life of the individual; and of numerous branching cords, the *nerves*, which connect up the central organs with all parts of the body. The central organs consist of brain and spinal cord, elaborately sheltered within the axial skeleton (fig. 26), and of a more subsidiary part lodged in the body cavity close against the backbone, and known as the sympathetic nervous system.

The Spinal Cord.—It is best to begin a consideration of these organs with the spinal cord or marrow, a soft cylindrical mass contained in the backbone, and continuous at one end with the brain, while at the other it tapers to a thread. This cord is protected by investing membranes, and in a cross-section (fig. 27) presents a somewhat singular appearance, due to its being made up of two sorts of nervous matter, white and grey, the former being external while the latter constitutes a sort of core, which in the section looks like a couple of cres-

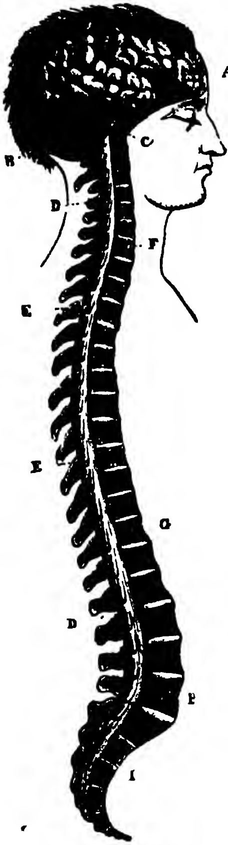


Fig 26 — Position of Brain and Spinal Cord

A, Right cerebral hemisphere, B, cerebellum, C, upper end of medulla oblongata D D, spinal cord with beginnings of spinal nerves, E F, processes of vertebræ, F G H, last vertebræ of neck, chest, and loin regions; I sacrum.

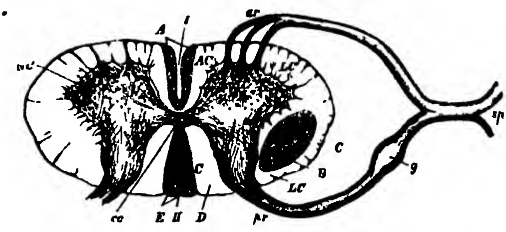


Fig 27.- Cross section of the Spinal Cord, dorsal side below. Partly diagrammatic. Magnified

N C, Groups of nerve-cells in grey matter, remaining capital letters indicate regions of white matter, *sp*, a spinal nerve, formed by union of dorsal (posterior) and ventral (anterior) roots, *pr* and *ar*, *g*, ganglion on dorsal root.

cents placed back to back. A further point of importance is the presence of a minute central canal, so that the cord can be regarded as a tube with small bore and very thick walls, somewhat as is the case with the stem of a thermo-

meter. The *grey matter* is mainly made up of angular or star-shaped structures of very small size, each of these being a *nerve-* or *ganglion-cell* (fig. 28). It is these cells which collectively make up the essential part of the central organs, while the *white matter* and the nerves consist of an infinite number of slender *nerve-fibres* which have a conducting function. To take an electrical analogy, the nerve-cells may be looked upon as batteries, while the nerve-fibres are comparable to wires. The analogy, however, is a very rough one, for here batteries and wires alike are alive, and there does not appear to be the same coupling up of nerve cells and fibres that exists between batteries and wires in an ordinary electric system. There is indeed a certain amount of connection, but how much is a matter of doubt. Not improbably the cells, to some extent, are able to act independently of fibres, recalling the wireless telegraphy which is now being developed.

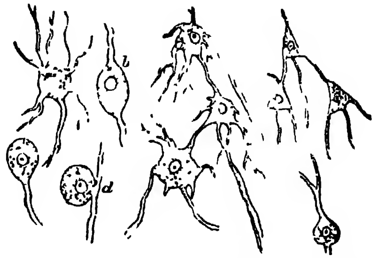


Fig 28.—Various Forms of Nerve cells b and d from ganglia on dorsal roots of spinal nerves Observe nucleus in centre of each

Subject to the brain, a large amount of control over the neck, trunk, and limbs is exerted by the spinal cord, and in accordance with this the parts in question are supplied by numerous pairs of *spinal nerves* which arise from the cord. The examination of any particular spinal nerve (fig. 27) will show that it takes origin in a couple of bundles of fibres which, from their position, are respectively known as the dorsal and ventral roots. It has been shown that, broadly speaking, the fibres of the dorsal root are carrying nerve impulses—telegraphic messages, as it were—to the central organs, while those of the ventral root carry such impulses away from them. To express this, the names afferent and efferent fibres (L. *affĕro,* I carry to; *effĕro,* I carry out) are respectively given. The *afferent fibres* convey information to the central organs about what is going on in the body or outside it, while the *efferent fibres* carry impulses from the central organs to the other parts of the body, with the result that certain actions take place, or it may be that actions in progress are modified or stopped.

The Brain.—The brain is an exceedingly complex organ, and is the centre of sensations and voluntary actions, besides, like the spinal cord, carrying on operations not dependent on the will. It consists of a central axis, which may be regarded as a forward extension of the spinal cord, and of various outgrowths from this. The brains of different kinds of backboned animals differ very largely from one another in the extent to which these outgrowths are developed. In the human brain they attain their largest proportions, and the most noteworthy of them (fig. 26) are the *cerebellum* in the hinder part of the brain, and the two *cerebral hemispheres* in front of these. It is the hemispheres which are of greatest interest, for the grey matter forming their outer layer, or *cortex*, appears to be the ultimate seat of reason, will, and intelligence. It can be mapped out into small areas or centres, which are partly motor, controlling special muscles, and partly sensory, concerned with the special sensations. We have, for example, a special motor area concerned with the muscles of the arm, and if this centre be injured, paralysis of the arm follows. Again, a special centre of vision has been recognized, and if this be damaged, the sight is more or less impaired. In fact, what are termed sensations of sight, hearing, taste, &c., depend on changes taking place in these centres consequent on nerve impulses which are conveyed to the brain along afferent nerve-fibres. The hemispheres are connected together by a broad band of nerve-fibres (corpus callosum), the presence of which is important as regards classification.

The spinal cord is not only a central organ capable of doing certain regulative work on its own account, but also serves as a channel of communication between the brain and those parts of the body supplied by the spinal nerves. The brain, however, communicates directly with the head and some other parts of the body by means of twelve pairs of *cranial nerves* which take origin from it. These differ in many ways from spinal nerves. Some of them are composed entirely of afferent fibres, which place sense organs in communication with the brain, *e.g.* the optic nerve connected with the eye, and the auditory nerve with the internal organs of hearing. Others are entirely composed of efferent fibres, *e.g.* three pairs of small nerves which do nothing but supply the muscles moving the eyeballs. Others, again, contain

both efferent and afferent fibres, as is the case with the remarkable tenth pair of cranial nerves, named vagus on account of their wandering course. Running along the neck, these nerves pass into the thorax, where they send branches to both heart and lungs, and, piercing the midriff, end in branches supplying the stomach.

The Sympathetic System.—This brief survey of the nervous system may be completed by referring to the *sympathetic system*, which consists in the main of a couple of slender cords running ventral to the backbone, and dilating at intervals into small swellings known as the sympathetic ganglia, containing nerve-cells, and therefore considered as collectively constituting a part of the central nervous system. They are connected with the spinal and some of the cranial nerves, and largely control the internal organs and blood-vessels, to which they send numerous branches. The working of the sympathetic system is entirely involuntary, a fortunate circumstance to which we owe the fact that we are very largely unconscious of the internal movements of the body.

SENSE ORGANS.—The sense organs have been described as the implements of the nervous system, gaining, as it does, information about the external world by their means. A sense organ may broadly be regarded as a more or less modified piece of skin adapted to receive impressions from some external agent (contact, heat, light, sound, &c.) or *stimulus* (L. *stimulus*, an ox-goad), and connected up with the central nervous system by a sensory nerve.

Fig. 29. Magnified View of a Papilla of Skin, with a Touch Corpuscle

The Skin as a Sense Organ.—The skin of the neck, trunk, and limbs is richly supplied with sensory nerves derived from the spinal cord, while the skin of the head and the linings of the mouth- and nose-cavities receive branches from the fifth cranial nerve. Connected with many of the smallest twigs of these nerves are microscopic bodies which are known as *touch-corpuscles* (fig. 29), because they are believed to have to do with the sense of *touch*. A finger-tip furnishes the best example. Upon it will readily be seen a series of fine ridges arranged in a characteristic manner, differing largely, however, in different individuals, and thus affording an important means of identification. Under these ridges,

imbedded in the deeper layer of the skin (dermis) are to be seen rows of touch-corpuscles. The sense of touch proper gives us information about bodies which actually come into contact with the skin, and how extensive such information may be is seen in the case of blind persons. The sequence of events before we feel a sensation when, say, a finger-tip touches any object, is somewhat as follows:—The first effect of contact is to cause some kind of to-and-fro movement in the minute particles (molecules) of which the touch-corpuscles are made up, or, to use more technical language, a "molecular vibration". The corpuscles may be called the "end-organs of touch", because they form the external end of the set of structures concerned with touch. Next follows a "nerve impulse" (which is another kind of molecular vibration) along the sensory nerve to the spinal cord and thence to the brain. Lastly, a part of the grey matter composing the external coat or cortex of a brain hemisphere is affected, a third variety of molecular vibration being set up in it. Then, and not till then, is a sensation of touch experienced, by which we know that something has happened in the finger-tip. What that something may be is judged by comparison with past happenings of a like nature. The sequence of events here very roughly described for touch applies, *mutatis mutandis*, to any other sense, and therefore will not be spoken of again; but it is important to bear in mind that all the various sensations—touch, taste, smell, hearing, and sight—are, so to speak, manufactured in the brain, and it is only as the result of long practice that we learn to recognize them as resulting from changes set up in end-organs by different external agents (stimuli), enabling us to form judgments about what is happening outside the body altogether.

The skin is not merely concerned with touch proper, but is also the organ of the *temperature-sense*, by which we learn something about the condition of external bodies as regards their condition with reference to heat or cold.

The Sense of Taste (fig. 30).—The object of this sense being to give us information about food, it is not surprising to find its end-organs limited to the lining of the mouth-cavity. The most obvious of these are contained in the mucous membrane of the tongue, upon the upper side of which organ, at the back, are to be noted a number of small projections or *papillæ*, in the sides of

which are imbedded minute ovoid taste-buds containing slender *taste-cells*. These cells are connected with nerve-fibres which have been usually regarded as coming from the ninth cranial nerve, though there is reason to believe that they really belong to the fifth. However that may be, there are only two sensations of taste proper, *i.e.* sweetness and bitterness, and the stimulus which initiates either of these must be something in a dissolved condition. Many so-called tastes are partly smells, and that such "flavours" are of this mixed nature is practically demonstrated by a cold in the head, which largely destroys what we popularly call taste, although only the nose is affected. We are able to smell the food in the mouth by reason of the fact that mouth-cavity and nasal cavities alike communicate with the pharynx (see p. 34). It must also be borne in mind that the lining of the mouth, especially that part of it covering the tongue, also ministers to the sense of touch. The tip of the tongue is even more sensitive in this respect than a finger-tip, and there is also good reason for thinking that what we call "acid tastes" are more properly to be regarded as varieties of touch.

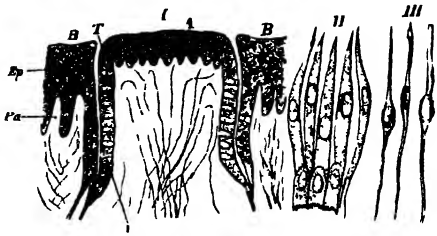


Fig. 30.—Section of Papillæ of the Tongue highly magnified

I A, Section of the central papilla B B, section of the surrounding elevation, *Pa* papilla of the dermis *Ep*, layer of epithelium, T taste buds II and III represent very highly magnified views of cells of the taste buds. Note their oval nuclei

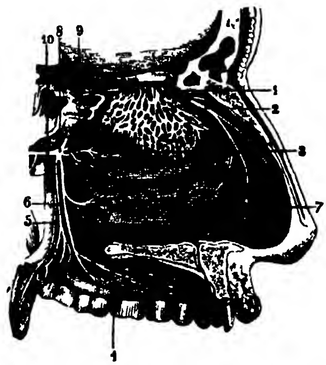


Fig. 31.—Distribution of Nerves over interior of Nasal Cavity, outer wall

1, Branches of nerves of smell—olfactory nerve, 2, nerves of touch to the nostril, 4, 5, 6, nerves to the palate springing from a ganglion at 8. 3, 7, 9, branches from one of the palate nerves to nostrils

The Sense of Smell (fig. 31).—The organs of smell have to do with testing the quality of the air taken into the lungs, and it is therefore natural that they should be situated at the beginning of the breathing passages. They consist of the two cavities of the nose, opening behind into the pharynx. The mucous membrane which lines the upper part of these cavities contains numerous slender *olfactory cells*, which are the end-organs of

smell, and are acted upon by gases and vapours. Fragrance and its contrary are the only smells to which the name can strictly be applied, as some so-called "odours", such as those of a pungent nature, are due to the delicate sense of touch connected with the nasal cavities. The first cranial or olfactory nerves are those of smell proper, and they supply the end-organs alluded to. As already mentioned, certain sensations which we are accustomed to call tastes are partly of the nature of smells.

The Organs of Hearing (fig. 32).—These complicated structures consist of two subdivisions—(1) the essential parts containing the end-organs, and (2) certain sound-conducting arrangements. (1) The essential parts constituting what is known as the *internal ear* are imbedded in the firm side-wall of the skull, and consist of a complicated bag, the *membranous labyrinth*, on each side. This bag is really a small portion of the skin, which has been folded in so as to reach a sheltered position and escape injury. If the head of an embryo chick be examined, a small pit will be seen on either side of it. This is the commencing internal ear, and later on the mouth

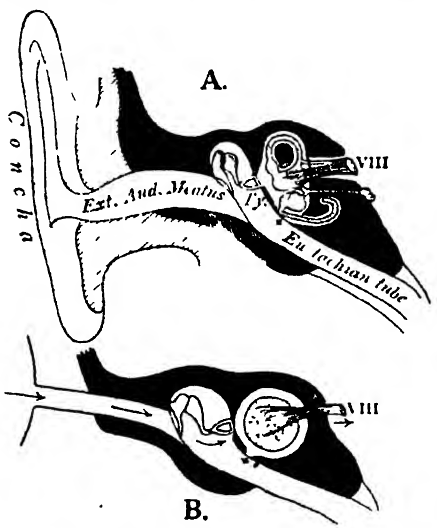


Fig. 32.—Diagrams of Auditory Organs natural size

Parts cut through are shaded, the close shading indicating the temporal bone. Membranous labyrinth dotted. *Ty*, Tympanic cavity. VIII, auditory nerve. Arrows indicate direction in which sound-waves and resultant nerve impulses pass. *A* is after Schwalbe, and B is a still simpler diagram.

of the pit closes, converting it into a minute vesicle lying just below the surface. This vesicle sinks inwards, and gradually assumes the complex shape characteristic of the labyrinth in the adult, while at the same time bony matter is formed round it. The lining of the labyrinth is made up in several places of slender *auditory cells*, which are the end-organs for hearing, and are supplied by the eighth or auditory cranial nerves. (2) The end-organs of hearing are stimulated by those vibrations of the air which are known as sound-waves, but, owing to the deep position of the

labyrinth, a special conducting apparatus, consisting of middle and external ears, is necessary. The *external ear* consists of the flap to which the name "ear" is applied in ordinary language, that of *concha* or *pinna* scientifically, and of a short auditory tube leading down into the head. Stretched across the inner end of this tube is a firm tympanic membrane. The *middle ear* consists of a tympanic cavity ("drum" of the ear) internal to the tympanic membrane, and communicating with the pharynx by a tube-like prolongation (Eustachian tube). The internal ear is situated close to the inner side of the tympanic cavity, and at one place the protecting bone is absent, leaving a little oval space, the oval window (fenestra ovalis), filled by membrane only. If this were perforated, the fluid which surrounds the labyrinth would escape into the tympanic cavity. Stretching across the cavity from tympanic membrane to oval window is a chain of minute bones, the auditory ossicles, called, from their shape, hammer, anvil, and stirrup. The handle of the first is fixed to the tympanic membrane, while the foot-plate of the last fits into the oval window. Sound-waves enter the auditory tube, throw the tympanic membrane into vibrations, like those of a drum-head, and this moves the chain of ossicles backwards and forwards, thus acting upon the membrane of the oval window, thereby affecting the fluid surrounding the labyrinth. The wall of the labyrinth itself is thus jolted, and the fluid it contains agitated. So far the vibrations (except the sound-waves themselves) are not molecular, but now begins the first part of hearing proper, for the auditory cells of the labyrinth are thrown into molecular vibration, followed by the transmission of impulses along the auditory nerve to the brain.

The Organs of Sight (fig. 33).—The eyes, which to a very large extent act together, are sheltered in bony depressions of the face known as the orbits, and are provided with muscles for moving them in different directions, which obviously largely adds to their efficiency. There are also other accessory structures, such as eyelids and tear-glands, the former protective, and the latter secreting a fluid which washes the front of the eye, and as it is done with passing down a narrow tube into the nose-cavity.

The eyeball is covered by three coats, of which the outermost, the *sclerotic*, is very tough, and forms what is called "the white" of the eye. A circular external area of this is the transparent

cornea, which permits light rays to enter. Within the sclerotic is a much softer *choroid coat* containing numerous blood-vessels· this, however, does not line the cornea and its immediate neighbourhood, but runs transversely across the front part of the eye to form the coloured part we call the *iris*, in the centre of which is a hole, the *pupil*. Optically speaking the iris is a diaphragm for regulating the amount of light entering the eye, and the size of its central aperture, the pupil, varies in size according to circumstances, becoming very small in a bright light and very large in a dim light. Lining the choroid is a third eye-coat, pulpy in consistency, and known as the *retina*. It contains the end-organs for sight (rods and cones), and acts as a sensitive screen upon which light falls. The second cranial or optic nerves run into the retina, branching within it to supply the rods and cones.

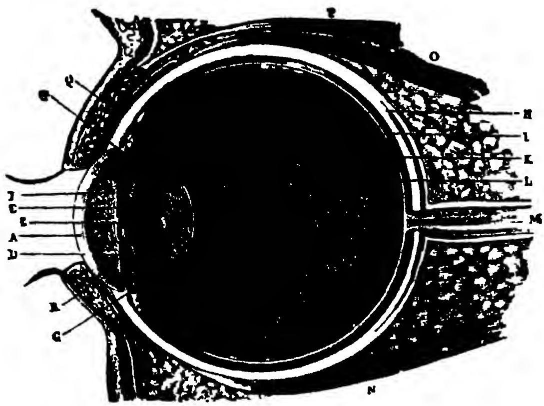


Fig 33 —Representation of a vertical cut through the Eyeball in its Socket

A, Cornea, B, aqueous humour, C, pupil, D, iris, E, lens, H, sclerotic; I, choroid; K, retina, L, vitreous humour; M, optic nerve, N, an eye-muscle; P, an eyelid-muscle, with an eye-muscle (O) below it, Q R, eyelids.

The eye is filled with refracting structures, of which the most important is the biconvex *lens*, placed just behind the iris. The small space in front of the lens is filled by a clear fluid, the *aqueous humour*, and the much larger space at its back by the jelly-like *vitreous humour*. Just as the lens of a photographer's camera forms a picture of surrounding objects upon the sensitive plate at the back of the apparatus, so do the refracting substances within the eye act with reference to the retina.

A study of the development of the eye shows that its sensitive part, the retina, is formed from an outgrowth of the brain, and as this organ is in reality a piece of skin folded in and much modified, the retina must be looked upon as of the same nature.

Common Origin of Sense Organs.—We have seen that all the sense organs agree with one another in the important point that their essential parts, *i.e.* those containing end-organs, are really modifications of part of the skin, though this is not apparent at first sight, and reference must be made to the facts of development in order to prove it. But as the different sense organs are adapted to respond to very different agents, it is only natural that they should be modified for the purpose, so that the ear, for example, possesses an elaborate sound-conducting apparatus, while the eye consists largely of refracting structures.

CHAPTER II

ESSENTIAL CHARACTERS OF VERTEBRATE ANIMALS. STRUCTURE AND CLASSIFICATION OF MAMMALS

VERTEBRATES AND INVERTEBRATES. — It has already been pointed out (p. 8) that Aristotle in his natural history drew what is perhaps the most important boundary line in zoology, *i.e.* the one dividing Backboned or Vertebrate Animals from Backboneless or Invertebrate ones.

The description which has just been given of the structure and functions of the human body will have given a rough idea of the leading characters of the Vertebrates, and it is now necessary to indicate those features which characterize the group as a whole. The following classes are here included:—

I. MAMMALS, or ordinary warm-blooded quadrupeds.—*Exs.*: Lion, Horse, Rabbit, Bats, Monkeys, Human Beings.
II. BIRDS.—*Exs.*: Fowl, Parrot, Ostrich.
III. REPTILES.—*Exs.*: Crocodiles, Lizards, Turtles, Snakes.
IV. AMPHIBIANS.—*Exs.*: Frogs, Toads, Newts, Salamanders.
V. FISHES.—*Exs.*: Herring, Salmon, Shark, Lamprey
VI. PROTOCHORDATES, including various low forms, none of which are familiar to most persons.

Essential Characters of Vertebrates.—The body is nearly always bilaterally symmetrical, though cases are known where this is only true for the very young animal while the adult is more or less asymmetrical. A good case in point is that of Flat-fishes, such as turbot, sole, and plaice, in which the young fry closely resemble those of other fish, but as development advances one eye is shifted round to the other side of the head. In a turbot (fig. 34), for example, the dark and light sides are not dorsal and ventral, as might at first sight be supposed, but left and right, both the eyes being situated on the former side, which is kept turned upwards during life.

Segmentation, or division of the body into a number of similar parts or *segments* from before backwards, is another characteristic of Vertebrates, but is not equally obvious in all of them. It is particularly well seen in the lancelet (Amphioxus), a small somewhat fish-like animal classed with the Protochordates (fig. 293).

The body of an average Vertebrate is divisible into *head*, *trunk*, and *tail*, though the last may be entirely absent in some terrestrial forms, as, *e.g.*, the frog, which, however, possesses a large tail in its tadpole stage. When *limbs* are present they are never more than four in number, in which case the fore- and hind-limbs may be much alike, as in a pig, lizard, or newt, or else they may be widely dissimilar, as in a bat or bird, where the fore-limbs are modified for the purposes of flight. One pair of limbs may be entirely absent, as in whales, which possess no hinder extremities, though there can be no doubt that such were present in the ancestral forms from which whales are descended. The complete absence of limbs in certain cases may be due to the fact that they never have been present, as in Protochordates; or it may be a case of the dwindling away and disappearance of members once possessed, as in snakes, which occasionally retain small and imperfect hind-limbs.

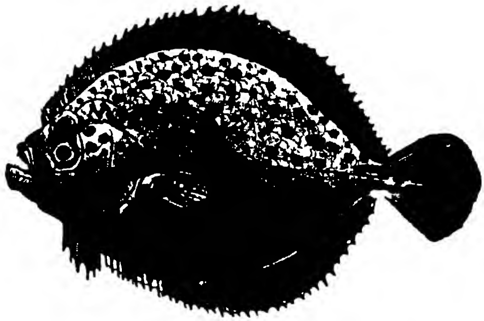


Fig. 34. - Left side (apparent dorsal side) of a Turbot

The *double-tube arrangement*, which has been described as characteristic of the human body, is found among Vertebrates generally, and running along the axis of the trunk between the two tubes is either a backbone proper, or at any rate a firm supporting rod which answers the same purpose. A rod of this sort, the *notochord*, is found throughout life in the lancelet, for example. It is not composed of bone or gristle, but of an elastic substance. Such a rod is found in the embryos of all Vertebrates, but as development proceeds it is usually more or less replaced by a *vertebral column* made of cartilage or bone, or both. The presence of a notochord at some period or other of life is one

of the most distinctive characters of Vertebrates, which for this reason are often termed CHORDATA.

In the vast majority of Vertebrates we find, at the beginning of the digestive tube, *jaws* having an up-and-down movement. Certain of the higher Invertebrates, *e.g.* lobster, scorpion, cockroach, also possess parts which are called jaws, but they are really limbs which move from side to side, are placed entirely outside the mouth, and do not form, as in a Vertebrate, a part of the head.

In all groups of Vertebrates we find that at some period or other of life there are certain slit-like openings on the side of the throat, by means of which the cavity of the pharynx communicates with the exterior (fig. 35). These openings in aquatic forms, such as fishes, become the *gill-slits* of the adult. Probably everyone has lifted up the flap or gill-cover, which is found on each side of the head in such a fish as a salmon or herring, and seen the red comb-like gills attached to the bars between these slits. And those who have not done this are likely to have noticed gold-fish or the

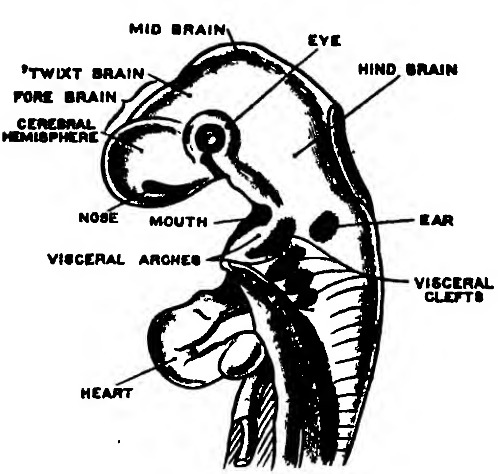


Fig 35.—Front part of Chick Embryo

like in an aquarium, and if so, will have observed that the animals continually open and shut their mouths, taking in water, which passes out again through these gill-slits in the process of breathing. In such terrestrial forms as Mammals, Reptiles, and Birds such slits are present in the embryo only (fig. 35), but they never perform any function, and ultimately close up altogether, only serving as a token that in the remote past the ancestors of these groups were aquatic forms, possessing gill-slits and breathing by means of gills. Such a statement as the last might appear very far-fetched, were it not that in the life-history of the frog, and other Amphibia, we can actually see a gill-possessing fish-like creature gradually turn before our eyes into a terrestrial animal,

breathing air by means of lungs and quite devoid of gills and gill-slits. For it is a familiar commonplace that the frog starts life as a "pollywog" or tadpole, which to all intents and purposes is a fish, and would be classed as such if it developed no further. In due course, however, the tadpole grows lungs, while at the same time its gills shrivel up and its gill-slits close, changes which are accompanied by growth of limbs and loss of tail, the ultimate product of these revolutionary proceedings being a frog.

All Vertebrates possess a *blood system*, consisting of a set of tubes in which blood is circulated, usually by the pumping action of a *heart* placed near the under or ventral side of the animal. In the higher groups the heart is much more complicated in structure than in the lower ones.

The chief part of the *central nervous system* in a Vertebrate is a thick-walled tube, the front part of which is larger than the rest and is termed the *brain*, while the rest is the *spinal cord*. This tube has a dorsal position. The sensitive parts of the characteristic *eyes* are developed as outgrowths of the brain.

A brief survey of the Vertebrate groups, with their subdivisions, may now be appropriately entered into, beginning with the Mammals and ending with the Protochordates.

MAMMALS

Mammals are justly regarded as being the highest group of Backboned animals, and a number of characters mark them off pretty sharply from the remaining groups. These characters, as well as others of less importance, have been for the most part dealt with in the sketch already given of Man, the highest member of the group.

Probably the two most striking features which characterize a Mammal are the possession of (1) hair and (2) milk-glands, both of which belong to the skin.

Fig. 36.—Section of Skin, showing Hair, Hair Follicles, and Glands.
a, Epidermis; *b*, dermis; *c*, base of hair; *d*, sebaceous glands; *e*, muscle attached to hair follicle.

(1) *Hair* (fig. 36).—In all cases we find that the epidermis gives rise to a more or less pronounced hairy covering, each hair growing from a deep narrow pit in the skin, called a hair-follicle. Opening into this are two little glands

(sebaceous glands), secreting an oily substance that may be regarded as a sort of natural pomatum. After a hair has attained a certain length it falls out, and is succeeded by another hair growing from the same follicle. Many animals at stated periods of the year undergo a sort of moult in preparation for the growth of a new coat. This is the case, for example, with horses, which lose their hair on the approach of winter and develop a thicker covering.

There is very great variation as to the amount of hair present, some aquatic forms, such as whales, being almost devoid of any such covering, which on the other hand is extraordinarily well developed in such creatures as sheep and goats. There may also be a localization of well-developed hair, as in the mane of horse or lion, and the beard of man and many apes. Not only are there these differences in amount of hair, but also in kind and colour. Both these points are illustrated by the races of mankind, which present such differing types as the fair wavy hair of many Europeans, the black straight hair of the Chinese, and the frizzly wool of negroes. These differences are not merely ones of colour, but shape, for the hairs of a Chinaman are almost perfectly cylindrical, while the wavy hairs are flattened to some extent, and the wool is much flattened, as in curling wood shavings. In the last case, too, the hairs are set obliquely in the skin. Even in a human being we can distinguish between the coarser hair of the head and the fine downy hair covering most parts of the body, but in many mammals such a distinction is much better marked, as in the fur-seal, which possesses coarse comparatively long hair, together with the soft close-set finer sort which makes the skin valuable commercially. A more violent contrast is seen in a hedgehog (fig. 52), where we find not only ordinary hair, but also spines, which are simply very large strong protective hairs, and this is carried a step further in porcupines.

The epidermis of Mammals also produces other structures, which are more or less allied to hairs. The horn of a rhinoceros is of this nature, and may be considered as a mass of fused hairs, a view which is confirmed by examination of sections under the microscope. The fringed scales of some armadilloes are to be looked upon in a similar light, while such structures as claws, nails, and the hollow horns of cattle are more remotely related.

Mammals exhibit the greatest variety in the *coloration* of the hairy covering of the body, and some of the colour-schemes

are of great beauty, as, for example, in tigers and leopards. As a general rule, the under side of the body is paler than the rest (see p. 22). In the inhabitants of cold climates it frequently happens that there is a well-marked distinction between summer and winter coats in the matter of colour. All these different arrangements are not haphazard, but bear a definite relation to the habits of the animal, commonly rendering them inconspicuous to foes or prey, &c. Such uses will be fully dealt with elsewhere, when the colours of animals in general will be considered.

(2) *Milk*.—One of the most noteworthy features regarding Mammals is the care taken by them of their young, a character which has much to do with the dominant position in the struggle for existence which has been gained by this group of animals. The word "gained" is used advisedly, for geological study shows us that this leading place was in earlier periods occupied by types of very different kind; *e.g.* the Reptiles constituted what may be called the last reigning Vertebrate dynasty prior to the Age of Mammals in which we now live. Just as in that age Man, the newest comer, has, in virtue of his intellectual qualities, dethroned his lower relatives and taken first place.

It is a matter of common knowledge that in the early part of their existence the young of Mammals are nourished by milk, a substance which also plays, in various forms, a most important part in the economy of human adults. As might be expected, milk is an exceedingly nutritious substance, and may be taken as the type of a perfect food. The composition of cow's milk is approximately as follows:

Water, . . .		87·0
Solids, consisting of		
1. Albuminoids (chiefly casein), .	4·0	
2. Carbohydrates (milk sugar), .	4·6	
3. Fats, . . .	3·7	
4. Inorganic salts, ...	0·7	
	—	13·0
		100·0

It will be seen (see p. 33) that all the necessary constituents of animal food are present, and it may be added that they are in the most advantageous proportions.

A Mammal possesses one or more pairs of ***milk-glands***, and their position varies considerably in different species, but in all

cases such a gland consists of an aggregate of blindly-ending tubes which are ingrowths of the epidermis. As a general rule, these tubes open externally upon a *teat*, but in the two lowest known Mammals this is not the case, there being a simple depression of the skin, within which milk-pores are seen.

Besides the two important characters just dealt with, the Mammalia are distinguished by others of scarcely less value, which may be conveniently dealt with under the headings employed when describing the anatomy of the human subject.

Endoskeleton (see pp. 25–32).—Two very noteworthy features enable one to distinguish the *skull* of a Mammal from that of other Vertebrates. One is the presence of two occipital condyles at the back, and the other is the fact that the lower jaw is made up of only two pieces united together in front. Birds and Reptiles possess only one such condyle, and this, in cases where a well-developed neck is present, allows the head a very free motion, as may be observed in a bird, though in this particular case the large range of movement is also in part due to the existence of very perfect joints in the neck itself. Amphibia, *e.g.* the frog, also have two occipital condyles, but their skulls differ from those of Mammalia in so many other ways that no one is likely to be led into error thereby. As to the nature of the lower jaw, it is made up of a considerable number of pieces in Vertebrates lower than Mammals.

The *backbone* of a Man is typically Mammalian in its main features, except that the tail region is much more reduced than is usually the case. We note that the individual joints are flattened, and that in the young state the body or centrum of each is made up of a central piece, to which a bony disc is united at each end. This character applies to all but the very lowest members of the group. A further typical feature, to which but very few exceptions are known, is found in the fact that the vertebræ of the neck are seven in number, even in a giraffe.

The skeleton of the human *limbs* is typical in many ways, the chief modifications of a special nature being seen in the structure of the lower limbs, especially as regards the peculiar arches of the pelvis. Such peculiarities are adaptations to the requirements of the erect attitude. But the various bones recognizable in Man are recognizable also in most Mammals, and it may in particular be remarked that the possession of five fingers and five toes is the

typical condition, though all sorts of reductions in number may take place, by which a fitness for special kinds of locomotion, &c., is brought about. The most extreme case is that of the horse, which possesses but one well-developed digit in each limb.

Digestive Organs (see pp. 34–38).—In most respects the digestive organs of Man may be taken as typical, especially as regards the fact that there are two sets of teeth, and that these teeth are of several kinds. The total of thirty-two for the permanent set is not, however, typical, a much nearer approach to this being found in the pig, which possesses forty-four teeth in all, arranged according to the following dental formula:—

$$i. = \frac{3-3}{3-3},\quad c. = \frac{1-1}{1-1},\quad p.m. = \frac{4-4}{4-4},\quad m. = \frac{3-3}{3\ \ 3} = 44.$$

Many Mammals, however, have undergone much greater reduction in the number of teeth than human beings, and in some species these structures have been lost altogether, as in the Great Ant-eater of South America. Porpoises and the like, on the other hand, have a very large number of teeth not divided into distinct kinds. The nature of the teeth, which is determined by the kind of food, is of great classificatory importance.

Circulatory Organs (see pp. 38–43) —Hot blood (about 98° F.), a four-chambered heart, with impure blood on its right and pure blood on its left side, and an aorta with its arch curving to the left, are the most characteristic features, and have all been dealt with in the preliminary sketch.

The necessity of maintaining the blood at a temperature often higher than that of the surrounding medium appears to be one reason for the possession of a thick coating of hair.

Respiratory Organs (see pp. 45–47).—No Mammal at any time possesses gills, though gill-slits are found in the embryo (see p. 62), but breathing is always effected by a pair of spongy *lungs* situated in the cavity of the thorax. There is present, as in Man, a partly muscular partition, the midriff or *diaphragm*, separating the cavity of the thorax from that of the abdomen, and materially assisting in the movements of breathing by which the air in the lungs is renewed.

Nervous System (see pp. 49–53).- The arrangements described in Man may be taken as fairly typical for Mammals in general, except as regards the *brain*, which is proportionately very much larger than in any other form.

It is characteristic that the cerebral hemispheres should be large, and united by a corpus callosum, while their surface is usually marked by more or less distinct convolutions. There is a relation between the intelligence of a Mammal and the size and complexity as regards convolutions of its hemispheres.

CLASSIFICATION OF MAMMALS

Existing Mammals fall into three natural groups, which are again subdivided into Orders, the arrangement being as follows.

A. EUTHERIA.—This group embraces the vast majority of Mammals, including all the highest forms and those with which we are most familiar in this country. The distinctive characters mostly require a specialist knowledge of anatomy to be appreciated, and it may suffice to state that the hemispheres of the brain are large and convoluted, and that the young are born in a comparatively perfect condition, never being sheltered in a pouch after birth, as is the case with the second group of Mammals.

The orders are as follows:

1. *Primates.* *Exs.* Man, Apes, Monkeys.
2. *Lemurs* (Lemuroidea).
3. *Bats* (Chiroptera).
4. *Insect eaters* (Insectivora).—*Exs.* Hedgehog, Mole, Shrew.
5. *Flesh-eaters* (Carnivora). *Exs.*. Dog, Cat, Bear, Otter, Seal.
6. *Cetacea.*—*Exs.*: Whale, Porpoise.
7. *Sea cows* (Sirenia).—*Exs.*. Dugong, Manatee.
8. *Elephants* (Proboscidea).
9. *Conies* (Hyracoidea)—*Ex.*: Syrian Hyrax.
10. *Hoofed Mammals* (Ungulata). *Exs.*: Tapir, Rhinoceros, Horse, Hippopotamus, Pig, Deer, Cattle, Giraffe, Camel.
11. *Gnawers* (Rodentia). *Exs.*: Squirrel, Rat, Porcupine, Rabbit.
12. *Edentates* (Edentata).—*Exs.*: Sloth, Armadillo, Ant-Eater, Pangolin.

B. METATHERIA.—The forms embraced by this group have smooth and relatively small cerebral hemispheres. The young are born in a very immature condition, and are usually sheltered for a time in a pouch ventral to the abdominal region of the mother. Within this pouch are situated the long teats, to which the young remain attached for some time, and these are so immature as to be at first incapable of sucking, the milk being squeezed into their mouths. Under such conditions they would be in imminent danger of choking were it not that the top of the

THE HIPPOPOTAMUS (*Hippopotamus amphibius*)

The Hippopotamus is closely related to the members of the Pig family, and, like them, does not chew the cud. It lives for the most part in water, inhabiting some of the great African rivers A closely allied species inhabited Britain during prehistoric times. The Hippopotamus is a remarkably bulky animal, and weighs from three to four tons when adult.

THE HIPPOPOTAMUS (HIPPOPOTAMUS AMPHIBIUS)

A STUDY FROM THE LIFE

windpipe projects into the back of the nasal passages, so that the feeding and breathing tracts are kept separate.

There are also two well-marked features of the skeleton, one concerning the lower jaw and the other the pelvis. The hinder corners or angles of the former are bent (inflected) inwards (fig. 37), while the latter possesses two extra bones (epipubic bones) which are at most represented by vestiges in members of the Eutheria.

There is only one order, *i.e.*:

13. *Pouched Mammals* (Marsupials), of which all the existing types are limited to Australi and its adjacent islands, with a few exceptions found in America.—*Exs.*: Kangaroo, Wombat. American Opossums.

Fig. 37. Lower Jaw of a Wombat from behind. Note inwardly bent angles.

C. PROTOTHERIA.—A very small number of Mammals constitute this group, and they are marked off from the higher forms by the possession of very remarkable characters. Agreeing with Marsupials in the characters of the brain, which is, however, of a still lower type, and the presence of epipubic bones, they differ from them and all other Mammals in the fact that they lay tough-shelled eggs. The young, when hatched, are nourished by milk, as in other cases, but the milk-glands possess no teats, simply opening upon a bare patch of skin. The Prototheria are also distinguished by the comparatively low temperature of the blood, the peculiar structure of the shoulder-girdles, and the fact that the intestine ends by opening into a chamber, the *cloaca*, which also receives the products of nitrogenous waste. As to the shoulder-girdle, it was mentioned in describing the human scapula (p. 30) that a coracoid process is present on that bone, and that the process in question must be regarded as the vestige of what in ancestral forms was a distinct bone. Prototheria possess a distinct coracoid bone (fig. 38), and also certain other bony elements in the shoulder-girdle, approximating in this respect to what is found in lizards among the Reptiles. It may indeed be noted generally that the peculiar characteristics of these lowest Mammals point to reptilian affinities.

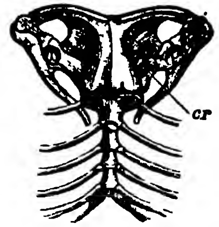


Fig. 38. Sternum and Shoulder-girdles of Duck Mole, from below. *cr*, Coracoid bone, just above which is the cup (glenoid cavity) for attachment of upper arm bone.

There is only one order of Prototheria, *i.e.*:

14. *Monotremes* (Monotremata), including only three living genera—the Duck-Mole (*Ornithorhynchus*), found in Australia and Tasmania (fig. 39): the Spiny Ant-Eater (*Echidna*) of Australia, Tasmania, and New Guinea; and the Spiny-tongued Ant-Eater (*Proechidna*), limited to the last-named island.

Fig. 39.—Duck-billed Platypus or Duck-Mole (*Ornithorhynchus paradoxus*).

Order 1.—Man and Monkeys (Primates)

1. *Man.*—Human beings are distinguished from all other Primates by the possession of vastly superior mental powers, but when structural features are regarded there is no marked difference, and every organ found in a man exists equally in an ape. The human brain, however, in correlation with the human intellect, is very much larger than that of any ape, and the convolutions of its hemispheres are much more complex. This is true for the lowest savage equally with the genius. Man, again, is the only Mammal to which the erect posture is easy and habitual, and we accordingly find that the lower limbs are specially modified with a view to the maintenance of this position. And as compared with the highest apes, the human upper limbs are comparatively short, and adapted to perform the most delicate manipulations.

Although the differences between the different races of mankind are well marked, all are now regarded as having sprung from a common stock, and as belonging to the same genus, Homo, and the same species, sapiens. The scientific name for Man, regarded as an animal, is therefore *Homo sapiens.*

II. *Apes and Monkeys.*—These are tropical mammals closely approximating to Man in structure, with opposable thumbs, eyes

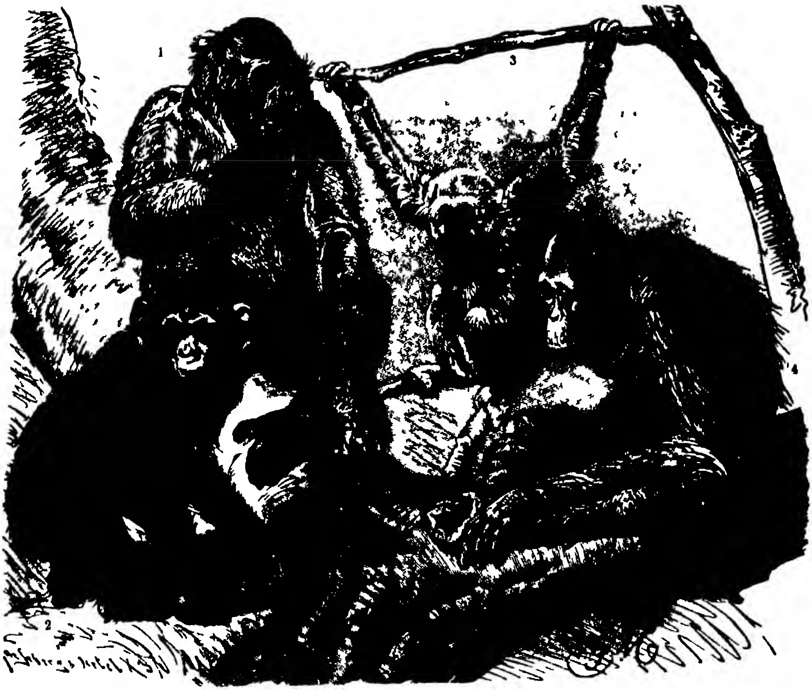


Fig 40 —Anthropoid Apes

1, Gorilla (*Gorilla Savagei*), 2, Chimpanzee (*Anthropopithecus niger*), 3, Silver Gibbon (*Hylobates leuciscus*), 4 Orang utan (*Simia satyrus*)

placed in orbits which are complete bony cups, teeth of the four typical kinds, and agreeing pretty closely in number with those of Man, and a pair of milk-glands situated on the chest. A point, related to the habit of climbing, in which these animals differ from Man, is found in the possession of opposable great toes.

Monkeys may be divided into three groups, corresponding largely to their geographical distribution: (1) Old World Monkeys, (2) New World Monkeys, and (3) Marmosets.

(1) *Old World Monkeys.*—These agree with Man in the number of the teeth, so that the dental formula is the same. They do not possess a well-formed projecting nose, but the nostrils are forwardly directed and close together, being separated by a narrow partition.

The *man-like* or *anthropoid apes* (fig. 40), come nearest to Man in structure. They include the Gorilla and Chimpanzee,

Fig. 41.—Entellus Monkeys (*Semnopithecus entellus*).

which are limited to the dense tropical forests of West and Central Africa, the Orang-utan, of Borneo and Sumatra, and the Gibbons of the East Indian Islands, further India, and South China.

The *tailed monkeys* constitute the remainder of the Old World section of ape-like forms. They are provided with hard patches (callosities) on the hind-quarters, and many of them possess cheek-pouches in which, as known to all visitors of zoological gardens and menageries, food can be temporarily stored.

Of these tailed monkeys, one group includes tree-inhabiting forms of comparatively slight build, a good example of which is the Entellus Monkey, or Hunuman (*Semnopithecus entellus*)

(fig. 41). It is held sacred by the natives of India, and is therefore allowed to commit serious depredations without let or hindrance. Another species of the same genus (*S. roxellanus*), found in the north of Thibet, has a well-developed pug nose; and in a Bornean form, the Proboscis Monkey (*S. nasica*), that

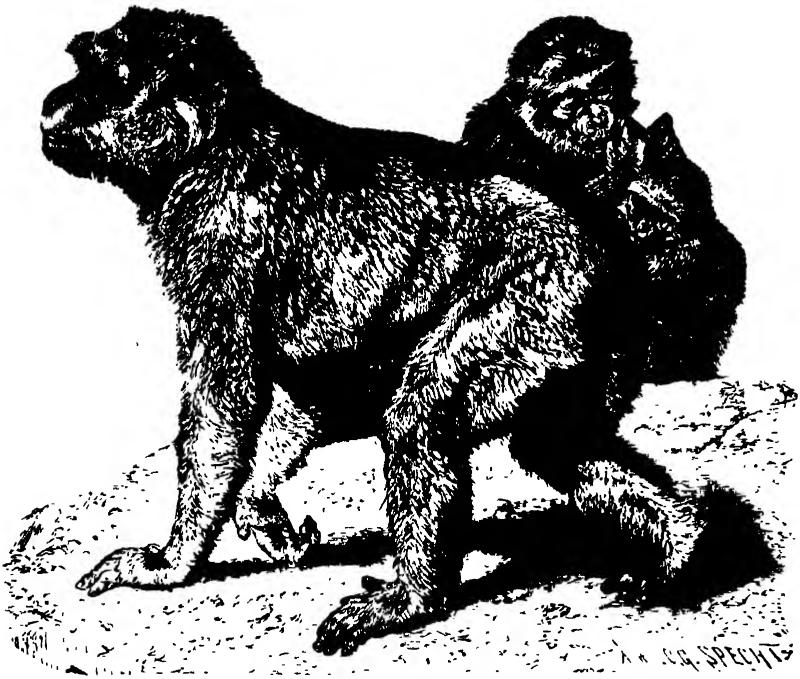


Fig. 42.—The Barbary Ape (*Inuus ecaudatus*).

part of the anatomy has a more classic outline, and confers upon the animal an expression of comic wisdom.

The *Colobi* of tropical Africa are comparable to the members of the preceding genus, from which they are distinguished by stronger jaws and a greatly reduced condition of the thumb. A typical species is the Guereza (*Colobus guereza*), of the Abyssinian highlands.

The *Guenons* are representatives of another African genus (*Cercopithecus*) closely related to Semnopithecus, but differing in the possession of cheek-pouches, and a relatively large thumb. The members of the different species live together in large communities, and on account of their thievish habits are regarded

with far from friendly feelings by the natives. One of the prettiest species is the West African Diana Monkey (*Cercopithecus diana*), in which the face is surrounded by a quaint-looking border of white fur drawn out below into a pointed beard. Another example is the Green Guenon (*C. sabæus*), which is among the common inhabitants of the monkey-house at the Zoo. The Moustache Monkey (*C. cephus*) is a handsome species of the same genus.

Fig. 43.—The Wanderoo (*Macacus silenus*).

Macaques, belonging to the genus *Macacus*, are of stouter build than the preceding species, and their tails at most do not exceed the body in length. Cheek-pouches are present. One species, the Magot, or Barbary Ape (*Macacus* or *Inuus ecaudatus*) (fig. 42), is of special interest, as being the only monkey with a range extending into Europe, for though its head-quarters are to be found in North Africa, it also occurs on the rock of Gibraltar, an interesting fact of distribution which has led to the popular belief that there is a submarine passage between Africa and Europe. The Boonder, or Rhesus Monkey (*Macacus rhesus*) of the East Indies, which is particularly common in the basin of the Ganges, has the same reverence extended to it by the natives as in the case of the Hunuman. Very similar in character is the Java Monkey (*M. cynomolgus*), but the Wanderoo (*M. silenus*) of Malabar is much more like a baboon (fig. 43). It is endowed with white beard and whiskers of ample proportions, and, being

the happy possessor of a wide range of mental characteristics, has been variously described as "a comedian" and "the philosopher among the monkeys". It should be noted that all the Macaques, with the exception of the Barbary Ape, are Asiatic forms.

The familiar *Baboons*, which live chiefly on the ground and have dog-like heads, are for the most part natives of Africa.

Fig. 44.—The Mandrill (*Papio mormon*)

The Arabian Baboon (*Papio hamadryas*), which once lived in Egypt also, was the prototype of Thoth, the old Egyptian God of Letters, and in this capacity, as well as in the humbler one of a simple ape, is often represented upon the ancient monuments of that country. It is a large and powerful creature of greyish colour, and the adult male, with his pinkish face, large mane on neck and shoulders, and bright-red swellings of large size on the hind-quarters, is by no means a prepossessing object. The West African Mandrill (*Papio mormon*) (fig. 44), however, is even more hideous. Its adornments are of a vivid nature, for there are blue

swellings on the face, and the large bare projections on the hinder regions are blue and red. The Yellow Baboon (*Papio babuin*) of West Africa is handsome by comparison with the two last species.

(2) *New World Monkeys* are a stage lower in development than those of the Old World, and consequently less human in appearance and structure. They always possess a tail, which is commonly used as a grasping organ, and may also serve as

Fig. 45.—Red Howling Monkeys (*Mycetes seniculus*)

a delicate organ of touch. The total number of permanent teeth is thirty-six, four more than in Man and the Old World apes, the excess being due to the presence of an extra premolar on each side of each jaw. There is also a difference in the nose, which has nostrils facing somewhat sideways, and separated by a broad partition.

Three distinct sections are recognized:—Naked-tailed Monkeys, Sajous, and Sakis.

In the *Naked-tailed Monkeys*, at least part of the long and powerful tail is devoid of hair on the under side and is used as a tactile and grasping organ. Among the noisiest of these forms are the *Howlers* of South America, such, for example, as the Red Howler (*Mycetes seniculus*) (fig. 45), in which the vocal organs are

provided with peculiar resonating structures that greatly add to the volume of sound produced in the dismal concerts to which these animals are addicted. Other illustrative species are the Barrigudo (*Lagothrix Humboldti*), with woolly fur, and the slender *Spider-*

Fig. 46. The Miriki or Woolly Spider Monkey (*Eriodes arachnoides*)

Monkeys, such as the Miriki (*Eriodes arachnoides*) (fig. 46) which are distinguished by the reduced condition of the thumb.

The most familiar New World monkeys are probably the *Sajous* or *Capuchin Monkeys*, belonging to the genus *Cebus*. The face is bare and wrinkled, and there are generally peculiar adornments of the nature of whiskers, &c. The long prehensile tail is completely covered with hair, and does not serve as an organ of touch. An example is the Weeper Capuchin (*Cebus capucinus*).

Lastly, in the *Sakis* the tail is not modified as a grasping organ. Examples are the Black Saki (*Pithecia Satanas*), with bushy tail and ample beard, found in the basins of the Orinoco and Amazons, and the Squirrel Monkey (*Chrysothrix sciurea*) of Guiana.

(3) The *Marmosets* or *Clawed Monkeys* of America are the lowest and least intelligent forms to which the name "monkey"

Fig. 47.—The Ouistiti or Common Marmoset (*Hapale Jacchus*).

can properly be applied. These small creatures, of which the Common Marmoset (*Hapale Jacchus*) may be taken as type (fig. 47), have claws on all the digits except the great toe, which is provided with a flat tail, and is opposable. The thumb, unlike that of an ordinary monkey, is non-opposable. The teeth are thirty-two in number, as in Man and the Old World forms, but the dental formula is different, for whereas these possess eight

premolars and twelve molars, a Marmoset has twelve premolars and eight molars, agreeing in the former particular with the New World monkeys proper.

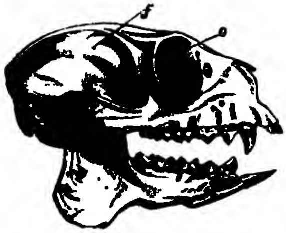


Fig 48 —Skull of Black Indris Lemur *f*, Temporal fossa *o*, orbit In this case the orbit is open behind and thus communicates with the temporal fossa

Order 2.—Lemurs (Lemuroidea)

This order includes a somewhat heterogeneous collection of tropical climbing mammals, of which the large majority are limited to Madagascar, while a smaller number are found in South-east Asia and in tropical West Africa. They have usually been included in the Primates, but on insufficient grounds, the chief common peculiarity being the possession of opposable thumb

Fig 49 —Ring tailed Lemur (*Lemur catta*)

and great toe, a character associated with the climbing habit. The brain-case is relatively smaller than in a monkey, and the orbits are not completely walled in at the back by bone (fig. 48). In accordance with their nocturnal habits these animals have

Fig. 50. The Spectre Tarsier (*Tarsius spectrum*).

large and sometimes even enormous eyes. There are generally more than one pair of mammary glands.

The Ring-tailed Lemur (*Lemur catta*) of South-west Madagascar may be taken as an average member of the order (fig. 49), while the little Spectre-Tarsier (*Tarsius spectrum*), with a body of only about 6 inches long, will serve as an example of the forms with especially large eyes (fig. 50). It is an East Indian and Philippine species.

Order 3.—Bats (Chiroptera)

Bats or "flittermice" differ from all other mammals in the possession of efficient flying-organs, differing entirely in structure, however, from the wings of a bird. A tough membrane extends between the body, limbs, and commonly the tail as well (fig. 51). The thumb is free, or partly so, and is provided with a strong curved claw, but the fingers are exceedingly long and slender, their use being to keep the membrane extended, thus

Fig. 51.—The Long-eared Bat (*Plecotus auritus*)

acting pretty much like the ribs of an umbrella. Bats, though nocturnal, have very small eyes, whence the expression "blind as a bat", but this is compensated by their long sensitive ears, and in many cases there are also curious leaf-like outgrowths on the nose. All our native bats, like the majority of forms included in the order, live on insects, and in accordance with this habit have numerous sharply-pointed teeth. A pair of mammary glands are present, situated on the breast. Although the general appearance of a bat's body enables us to understand why it should have received the old English name of flitter-*mouse*, these animals are in reality much more closely allied to hedgehogs and moles.

The order is divided into the two sections of Fruit-eating Bats and Insect-eating Bats.

The comparatively small section of *Fruit-eating Bats* only

includes the so-called Flying-foxes, which are natives of the Old World, Australia, and the South Sea Islands. The cheek-teeth have flattened crowns adapted for chewing, and there is generally a claw on the first finger as well as on the thumb. A typical species is the Kalong (*Pteropus edulis*) of the East Indies.

The *Insect-eating Bats* are by far the larger section, and include all our undoubted native species, twelve in number. All the cheek-teeth have sharp-pointed crowns, there is a claw on the thumb only, and the snout is shorter than in the fruit-eating forms. There are two families:—The True Bats (Vespertilionidæ) and the Leaf-nosed Bats (Phyllostomata).

In the *True Bats* (Vespertilionidæ), which are cosmopolite, the nose is simple in form, but there is a sensitive pointed projection from inside the ear to which the name of "earlet" (tragus) has been given.

A common British kind is the Long-eared Bat (*Plecotus auritus*) (fig. 51), abundant in the wooded regions of Europe, and ranging as far as India.

The European kinds which possess the greatest powers of flight belong to the genus *Vesperugo*, and include the Noctule (*V. noctula*) and the Pipistrelle (*V. pipistrellus*), which are respectively the largest and smallest of our native species.[1]

The *Leaf-nosed Bats* (Phyllostomata) are for the most part natives of the tropics, and differ from the preceding family in the possession of outgrowths from the nose, which serve apparently as special organs of touch. The food is not limited to insects, but may also include fruit, and some of them attack birds and mammals of other groups. A comparatively small and simple nose-leaf is found in the cave-inhabiting form to which reference is frequently made in works on Egyptian exploration (*Rhinopoma microphyllum*). A larger nose-leaf is present in the South American *Vampires*, which have earned an unenviable notoriety on account of their blood-sucking propensities, though an enormous grain of salt must be added to the numerous legends and stories which are current. The largest species is the True Vampire (*Phyllostoma spectrum*), which with its sharp front teeth is able to inflict a small wound

[1] The remaining British members of the family, omitting doubtful cases, are:—Hairy-armed Bat (*Vesperugo Leisleri*), Serotine Bat (*V. serotinus*), Bechstein's Bat (*Vespertilio Bechsteinii*), Natterer's Bat (*V. Nattereri*), Daubenton's Bat (*V. Daubentonii*), Whiskered Bat (*V. mystacinus*), and the Barbastelle (*Synotus barbastellus*).

in the body of a sleeping animal, the toes being the region favoured in the case of human beings. It is, however, only fair to add, that insects, or even fruit, are the favourite articles of diet.

A very complicated nose-leaf is found in the Old World forms belonging to the genus Rhinolophus, which are known as *Horse-shoe Bats.* Though these range from England to Tasmania, their head-quarters are in the southern parts of Asia. Only two forms, both of which occur in Britain, are found in Europe north of the Alps. These are the Lesser Horse-shoe Bat (*Rhinolophus hipposideros*) and the Greater Horse-shoe Bat (*R. ferrumequinum*).

Order 4.—INSECT-EATERS (Insectivora)

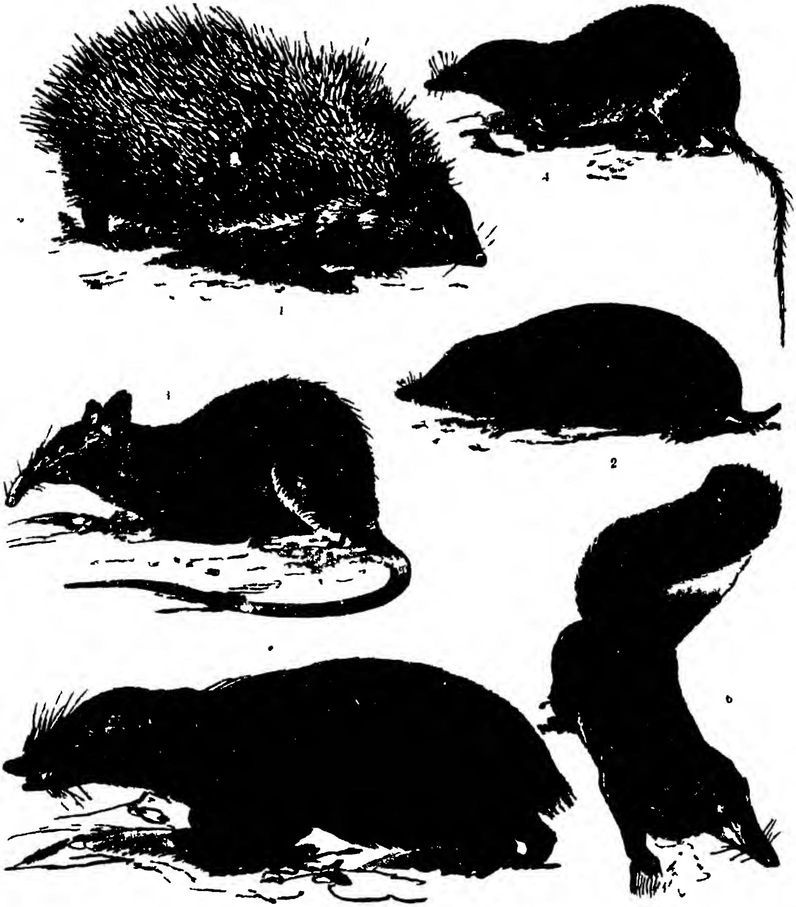
Insectivores (fig. 52) are small nocturnal mammals of low organization, adapted for preying upon insects, worms, snails, and other small creatures, for the seizing and holding of which their sharp-pointed teeth are peculiarly well adapted. There is generally a long pointed snout, suited for poking into the small corners and crevices inhabited by their prey. As might be expected in a primitive group like this, there are the typical number of digits, *i.e.* five on each hand and foot, and all are provided with claws. Several pairs of mammary glands are found in the abdominal region. Six groups of the Insectivora may be distinguished:—Banxrings, Jumping-Shrews, Desmans, Shrews, Hedgehogs, and Moles.

Banxrings or *Tree-Shrews* are arboreal forms which somewhat resemble squirrels in appearance, chiefly owing to the presence of a large bushy tail; but the long pointed snout is characteristically insectivore. A typical form is the Bornean Tree-Shrew (*Tupaia tana*).

The African group of *Jumping-Shrews* includes small long-snouted creatures common in desert regions, and distinguished by the relative length of their hind-limbs, upon which they spring actively about. The Elephant-Shrew (*Macroscelides typicus*) of South Africa is a good example.

Desmans are swimming forms found in Thibet, West Africa, South Russia, and North Spain. One of the best-known species is the Musk-Shrew (*Myogale moschata*) of the Volga and other Russian rivers.

All the preceding are small groups, but the mouse-like *Shrews* include a large number of species, and are found in all parts of the world except South America and Australia with its related



F[illegible] Insectivores

1 Hedgehog (*Erinaceus*) 2 Mole (*Talpa*) 3 Elephant Shrew (*Macroscelides*) 4 Shrew (*Crocidura*) 5 Tanrec (*Centetes*) 6 Ba[illegible]

islands There are three British species, the Common Shrew (*Sorex vulgaris*), the Lesser Shrew (*Sorex minutus*) and the Water Shrew (*Crossopus fodiens*) The two first are the smallest British mammals, and indeed the group includes the smallest known mammals found in any part of the world, one

species, the Tuscan Shrew (*Crocidura Etrusca*), being under an inch and a half long, with a tail one inch in length

The Common Shrew was an object of superstition in the Middle Ages, being looked upon as an enemy to domestic animals,

Fig. 53.—The Colugo or Flying Lemur (*Galeopithecus*)

and by way of antidote it was often immured alive in a hole cut in the trunk of an ash tree

The Common Hedgehog (*Erinaceus Europæus*) is a well-known type of a fairly large Old World group, which may broadly be taken to include hedgehogs proper, the spineless Agouta (*Solenodon*) of Cuba and Hayti, and the Tanrecs (*Centetes*, &c) of Madagascar, some of which are spiny The last are adapted to very various habits

The Common Mole (*Talpa Europæa*) is our British representative of a large group mainly distributed through the temperate parts of the northern hemisphere, and structurally modified so as to fit them for a burrowing habit. Related to them are the *Golden Moles* of the Cape, in which, however, the digits of the hand are reduced to three, and the fur has a beautiful iridescent sheen.

A remarkable animal, native to the East Indies, known as the Colugo, or Flying-Lemur (*Galeopithecus*), is probably best regarded as constituting a specialized group of the Insectivora. On each side of the body (fig. 53) there is a fold of skin which connects together the limbs and tail, and acts as a parachute, facilitating progress from one branch to another.

Order 5.—Flesh-Eaters (Carnivora)

This large, dominant, and widely distributed order of mammals includes a great diversity of widely differing forms, nearly all of which, however, are adapted for preying on weaker animals. In accordance with this the digits generally possess sharp claws, and the strong lower jaw, moved by very powerful muscles, is united to the skull by a well-marked hinge-joint (see p. 28), while large canines and cheek-teeth with cutting crowns are also characteristic. Carnivores possess considerable intelligence, particularly so in the domestic forms, such as cat and dog, and some, at least, of their senses are very acute.

The group is divided into two sub-orders—I, the true Carnivora, or Fissipedia; and II, the aquatic forms, or Pinnipedia. The former include most of the species, and Cat, Dog, and Bear may be taken as the leading types, of which the first is most specialized for flesh-eating, while the last is least so.

I. Fissipedia.—It is customary to divide the forms of this sub-order into Cats. Dogs, and Bears, using these words in a very wide sense.

CATS

These Carnivores have their feet lifted off the ground (fig. 54) so as to walk upon the digits (digitigrade), and their teeth are fewer in number and more specialized than is the case in the other two groups. There are four families:—1. Cats Proper (Felidæ);

THE TIGER (*Felis tigris*)

The Tiger is a typical member of the Cat family (*Felidæ*), which includes the most specialized forms belonging to the order of flesh-eating mammals. Tigers have a wide range, from India to south-east and east Asia, and the variety which lives in the more northerly part of the last area is possessed of a thick almost woolly coat. The animal figured is one of the familiar Indian kind, sometimes distinguished by the name of Royal or Bengal tiger.

The striped skin of this creature is a typical case of *aggressive general coloration*, harmonizing with the colour-scheme and confused light and shade of his native haunts, and thereby preventing the contemplated prey from taking premature alarm.

THE BENGAL TIGER—(FELIS TIGRIS)

2. Viverrines (Viverridæ); 3. Hyænas (Hyænidæ); and 4. Earth-wolves (Protelidæ).

1. *Cats Proper* (Felidæ) include a vast variety of forms, among which are the most highly specialized and the most rapacious of Carnivores. The teeth are fewer than in the other families and adapted to an exclusively animal diet, and the claws are usually prevented from getting blunt by being withdrawable into special sheaths, as everyone must have noticed in the domestic cat (fig. 55). Members of the family are to be found in all the continents except Australia, and they include (1) the True Felines, (2) the Lynxes, and (3) the Hunting Leopards.

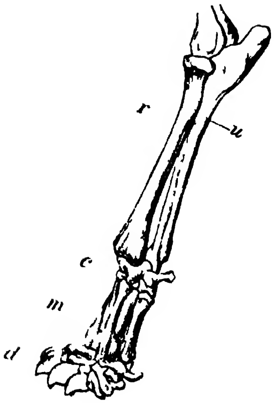
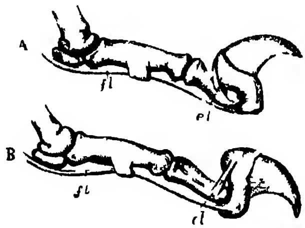


Fig. 54.—Lower part of the fore limb of a Lion, to illustrate the digitigrade structure. r, Radius; u, ulna; c, carpal bones; m, metacarpals; d, bones of digits.



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(1) *True Felines* (genus *Felis*) have comparatively short strong legs, and differ among themselves chiefly in the matter of size and in the coloration and markings of the skin. The Lion (*Felis leo*) is the only species which, fortunately for the natives, does not possess the power of climbing trees, and the absence of stripes or spots may be noted. The mane of the male is also a characteristic feature. Lions are chiefly found in Africa, but also range into the south-west of Asia. The Tiger (*Felis tigris*) is the equal of the lion as regards both size and strength, and its stealthy habits render it much more dangerous. The dark stripes on the skin are very characteristic, and their presence makes the animal very inconspicuous in its natural surroundings. Both in Africa and Asia spotted felines are to be found, to which the names Leopard and Panther are indifferently applied. We have, for

example, the African Leopard (*Felis leopardus*) and the Asiatic Panther (*Felis panthera*), which closely resemble one another. Various small felines are native to Asia and Africa, one of them, the Fallow Cat (*Felis maniculata*), being probably the form from which the domestic animal is descended. It was venerated and embalmed by the ancient Egyptians, and its present range includes North-east Africa and part of South-west Asia. An European species, the Wild Cat *par excellence* (*Felis catus*), is probably native to Britain but is now practically limited to the more remote parts of Scotland.

All the true felines so far mentioned belong to the New World, but forms of similar kind are also found on the American continent. Of these the Jaguar (*Felis onca*), resembling a large leopard in its characters, is distributed through the whole of South America to the southern part of North America, while the Puma (*Felis concolor*), a much less dangerous form, ranges from Canada to Patagonia. There are also smaller species, *e.g.* the Pampas Cat (*Felis pajeros*), which is a native of Patagonia, and is not unlike the European Wild Cat.

(2) *Lynxes* (genus Lynx) have longer legs than the true felines, and a smaller number of teeth, indeed their dentition is more specialized than in any other carnivorous genus. They are further distinguished by tufts of hair on the tips of the ears and by the shortness of the tail. Most of them are restricted to the northern hemisphere. There are two European species, of which the smaller, the Spanish Lynx (*L. pardinus*) is only found in the Peninsula, while the Polar Lynx (*L. vulgaris*) is now chiefly found in Scandinavia and Russia (fig. 56).

(3) The third genus (Cynailurus) of the Felidæ includes the *Hunting Leopards*, which look something like ordinary leopards, but have slender limbs and non-retractile claws. Their range includes Africa and South-west Asia, and the best-known form is the Cheetah (*C. jubatus*) of the latter region, which is trained for hunting purposes.

A ferocious cat-like animal, the Foussa (*Cryptoprocta ferox*), found only in Madagascar, and sometimes considered as constituting a distinct family, may be mentioned here as a form intermediate in some respects between the present family and the one next to be described.

2. The *Viverrines* (Viverridæ) are small carnivores represented

by numerous species in the warmer parts of the Old World The long slender body is provided with short legs the long bushy tail tapers to a point and the snout is somewhat long The teeth are more numerous and not so typically carnivorous in type as in the Felidæ Two sub families are distinguished which differ in the

Fig 50 — The Polar Lynx (*Lynx* [illegible])

structure of the feet and in other ways These are (1) the Civets and (2) the Mangoustis

(1) *Civets* are not unlike cats in their general appearance and like them are digitigrade and able to retract their claws One species, the Common Genet (*Genetta vulgaris*) is found in Spain and South France, its range also including those parts of Morocco and Algeria which are north of the Atlas Mountains Well known on account of the disgusting odour which they emit are the African Civet-Cat (*Viverra civetta*) and the Indian Civet Cat (*V zibetha*) (fig 57)

(2) *Mangoustes* are smaller than civets, and somewhat weasel like in appearance. The long toes are provided with non retractile claws, and the animal does not walk in the same tiptoe fashion as the cats or civets. Most of the species are African but some

Fig. 57. The Indian Civet Cat (*Viverra zibetha*)

are characteristic of South Asia, and one ranges into Europe. A common type is the Egyptian Ichneumon (*Herpestes ichneumon*), venerated by the ancient Egyptians probably on account of the services rendered by it in the destruction of snakes and the eggs of the crocodile. All sorts of wonderful stories were once current

about this animal's supposed habit of entering the crocodile's mouth for the purpose of preying upon its vitals, and its imagined knowledge of herbs acting as antidotes to the bite of a poisonous serpent A smaller species (fig 58), the Mungoose (*Herpestes griseus*), is undoubtedly of great use to the inhabitants of India, on account of its propensity for destroying snakes and rats Here again natives believe that the animal is acquainted with antidotes

Fig 58 —The Mungoose or Grey Ichneumon (*Herpestes griseus*)

to snake-bites One species of Mangousti (*Herpestes Widdringtoni*) is found in the south of Spain.

3 The family of *Hyænas* (Hyænidæ) includes only three species of powerfully-built though not very large carnivores, two of which are limited to Africa south of the Sahara. A rather peculiar appearance is given by the greater length of the fore-limbs and the presence of an incipient mane Hyænas are digitigrade, and the four toes of each foot, both fore and hind, are provided with non-retractile claws The excessively strong jaws are provided with teeth of marked carnivorous type, and the biting apparatus is powerful enough to successfully negotiate the hardest bones Carrion is the chief food The Spotted Hyæna (*Hyæna crocuta*) and Brown Hyæna (*H. brunnea*) are limited to South Africa, while the Striped Hyæna (*H. striata*) has a much wider distribution, inhabiting the temperate and warm parts of both Africa and Asia.

4. The family of *Earth-Wolves* (Protelidæ) is instituted for the reception of a single species, the Earth-Wolf (*Aardwolf*) of

the Cape (*Proteles Lalandii*), which is a burrowing form looking much like a small hyæna (fig. 59). It is, however, a distinct type.

Fig. 59 – The Earth Wolf or Aardwolf (*Proteles Lalandii*)

as shown by the insignificant cheek teeth and other anatomical characters.

DOGS

Dogs, if one includes under that term not only the species commonly so called, but also wolves, foxes, and other similar forms, are a large group of carnivores distributed over the greater part of the world. They are not so highly specialized as the cats, this being shown, for example, by the fact that their teeth are more numerous and not of so highly developed carnivorous type. The legs are long and adapted for running, and there are five toes on each fore-foot and four on each hind-foot, all provided with blunt non-retractile claws. Nearly all the members of the group belong

to the genus *Canis*, and the more robust species, with a rounded pupil to the eye, are known as *Wolves.* Of these the largest species is the Common Wolf (*Canis lupus*), which has a wide distribution through the cold and temperate parts of the northern hemisphere, and was at no very remote period a native of Britain.

Fig. 60.—The Sahara Fox or Fennec (*Canis zerda*)

As is well known, it hunts in packs, like many other dog-like animals, and this habit at times renders it formidable even to man. Few animals play a larger part in legend and fable, from the time of Æsop down to Uncle Remus. The Coyote or Prairie Wolf (*Canis latrans*) is a smaller North American species. Closely related to the wolf is the Jackal (*Canis aureus*), a much smaller animal, with a fox-like appearance. It ranges from India to Central Africa, and is also found in Greece and Dalmatia.

It has been pointed out that the domestic cat is probably the descendant of one particular wild species, but this is not the case

with dogs, these seeming to have a more varied origin. It is possible that the Dingo or Native Dog (*Canis dingo*) of Australia, which is especially interesting from the paucity of higher mammals in that continent, ought not, properly speaking, to be regarded as a wild form in the ordinary sense, but as the descendant of domesticated dogs introduced by man.

Foxes, as represented by their more characteristic species, are distinguished from wolves by a narrower snout, larger ears, shorter legs, and more bushy tail. The pupil of the eye, instead of being circular, is a vertical oval. A good type is our native species, the Common Fox (*Canis vulpes*), which is as widely distributed as the wolf, and represented by many different varieties. No animal figures more prominently in fable and legend, a somewhat exaggerated estimate being usually taken of its wisdom. Among related species the smallest and prettiest is undoubtedly the Fennec or Sahara Fox (*Canis zerda*), distinguished by the very great size of its ears (fig. 60).

BEARS

These are carnivores which walk upon the soles of the feet, or in other words are plantigrade (fig. 61), and their teeth are not so specialized as in cats and dogs, some of the molars possessing crowns adapted for crushing food instead of merely dividing it. This is in accordance with the diet, which commonly includes both animal and vegetable items.

Fig. 61.—Skeleton of Hind-limb of Bear, to illustrate the Plantigrade Structure. *r*, Radius; *u*, ulna, *t*, ankle-bones; *m* and *d*, bones of digits; *ca*, heel-bone.

The group is divided into three families:—1. Small Bears (Procyonidæ); 2. Large Bears (Ursidæ); 3. Badgers, Weasels, and Otters (Mustelidæ).

1. The *Small Bears* (Procyonidæ) are probably best known in the person of the Common Raccoon (*Procyon lotor*), a very active and inquisitive creature native to the forests of North America. As the specific name indicates (Lat. *lotor*, a washer), it has the curious habit of washing its food (fig. 62).

2. *Bears* (Ursidæ) are much larger and clumsier animals, familiar to all from menagerie and zoo specimens. Though pretty

widely distributed, they are not found in Africa south of the Sahara, nor in the Australian region, and are but scantily represented in South America. The Common or Brown Bear (*Ursus arctos*) (fig. 63), which is the species once native to Britain, is

Fig 62.—The Common Raccoon (*Procyon lotor*)

found in suitable localities throughout the whole extent of the Old World north of the Atlas and Himalaya ranges. He figures as the companion of wolf and fox in many fables and stories. Although the Brown Bear is no mean antagonist, it is surpassed both in size and fierceness by the Grizzly Bear (*Ursus ferox*) of the Rocky Mountains. The Polar Bear (*Ursus maritimus*) is of even greater size, and is indeed the largest living carnivore.

Fig. 63.—Brown Bears *Ursus arctos* (From an instantaneous photograph)

3. *Badgers*, *Weasels*, and *Otters* (Mustelidæ) together make up a family of which the majority of members are small in size, and

Fig. 64.—The Common Badger (*Meles taxus*)

which is of considerable economic importance since it is the source of many valuable furs.

Badgers are plantigrade forms with stoutly-built body and strong, short legs, armed with powerful claws used for burrowing. There are stink-glands opening near the root of the tail The Common Badger (*Meles taxus*) (fig 64) is commoner in some parts of Britain than generally supposed, for as a nocturnal and burrowing animal it is naturally seldom seen The colour presents a reversal of the usual condition of things among animals for the upper side of the body is light and the under side dark instead of the opposite Our native form ranges right across the temperate parts of Europe and Asia from Britain to Japan Other genera are found in Africa, South Asia and North America Closely related to the badgers are the *Skunks*, which range throughout both North and South America Undoubtedly the most graceful creatures of the kind, they are at the same time the most offensive, possessing as they do the power of ejecting to a considerable distance a fluid of indescribably disgusting odour secreted by their well-developed stink-glands

Fig. 65 The Weasel (*Putorius vulgaris*)

Martens and *Weasels* constitute a group, of which the most typical members are small lithe animals with an elongated narrow body and a long bushy tail. Most of them are digitigrade, and the claws may be retractile The largest British species is the Pole-cat (*Putorius fœtidus*), found in rapidly diminishing numbers

in various districts of Great Britain. Its local name of "foumart" (*i.e.* foul marten) has reference to the evil odour which it possesses, due to the same cause as in the badgers. The ferret is simply a domesticated variety of this animal. There are three other native species of marten: (1) the Stoat (*Putorius erminea*), which in its winter coat is known as the Ermine; (2) the Pine Marten (*Mustela martes*); and (3) the Weasel (*Putorius vulgaris*), which is smaller than the rest (fig. 65). The Stoat and Pine Marten are found in Ireland as well as in Great Britain.

The Sable (*Mustela zibellina*) of Russia-in-Asia is the most valuable fur-yielding member of the group, while the Glutton (*Gulo borealis*) of the Arctic regions has earned an unenviable reputation for voracity, though this has been much exaggerated.

Otters are Mustelines adapted for an aquatic life, as seen in the flattened tail and webbed feet. Our native species, the Common Otter (*Lutra vulgaris*), is found both in Europe and in Asia north of the Himalayas, including Japan.

II. PINNIPEDES (fig. 66) include sea-lions, walruses, and ordinary seals, in all of which the limbs are converted into flippers. In the first two groups the hind-limbs can be turned forward to assist in a clumsy sort of progression on land, but in the seals proper they are permanently turned backwards and bound up by folds of skin with the tail so as to form a fin.

The *Walrus* (*Trichechus rosmarus*) of the Arctic regions is remarkable not only for its flipper-like limbs but also in the reduced and specialized nature of its dentition, which is adapted for obtaining and crushing shell-fish and sea-urchins. Front teeth are altogether absent in the adult, and the upper canines are great tusks with which the food is dug up, and which also serve as weapons. There are ten cheek teeth with flattened crowns, three on each side above, and two on each side below.

The *Sea-Lions* or *Eared Seals*, so named from the presence of a small pinna, range all round the world in the colder parts of the southern hemisphere, and are also found in the North Pacific. A good type of the group is Steller's Sea-lion (*Otaria Stelleri*), which is most abundant in the neighbourhood of Behring's Straits, from which it ranges south to California and Japan. Its sharp-pointed teeth are well suited for the capture of fish.

The *True Seals* are more thoroughly adapted to an aquatic life than the two other groups of Pinnipedes, and have a much

wider distribution, being absent only from the shores of the East Indies and Africa. They are also found in some inland seas, as the Caspian, the Sea of Aral, and Lake Baikal, which is one of the proofs that these were formerly connected with the Arctic

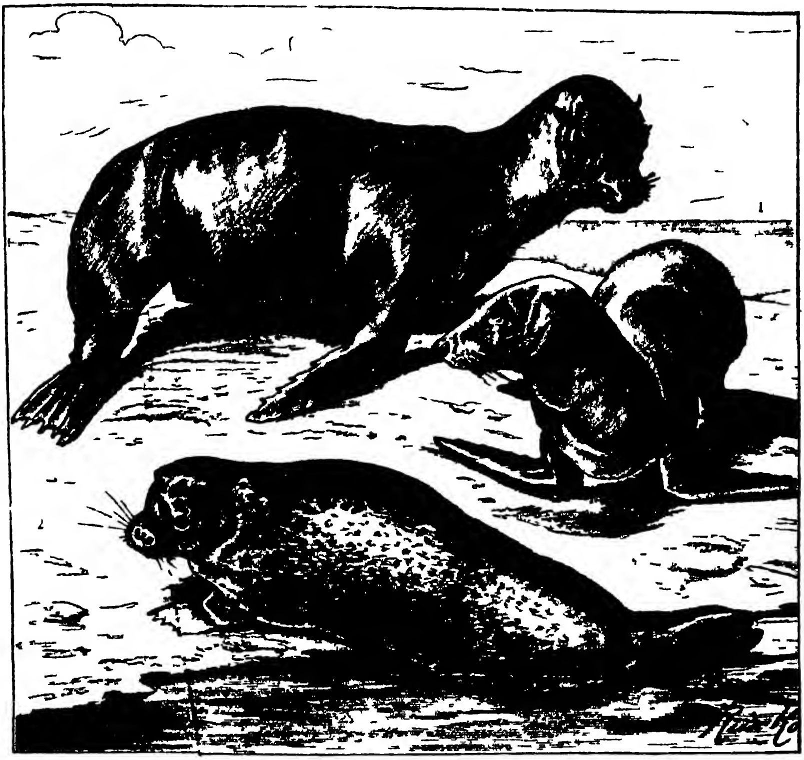


Fig. — Pinnipedes 1, Eared Seals (*Otaria*) 2 Common Seal (*Phoca*)

Ocean. Like the sea-lions, they are adapted for preying upon fish. Five species of seal are known to British waters, of which the Common Seal (*Phoca vitulina*) may be mentioned. The commonest sort in the seas of the far north is the Greenland Seal (*Phoca Grœnlandica*), one of the chief victims to seal-fishers.

Order 6—Whales and Porpoises (Cetacea)

The Cetaceans are mammals which are completely adapted for an aquatic life, being so much modified for that purpose as to be commonly mistaken for fishes, which they superficially resemble

in the general form of the body. Hair is practically absent in the adult, though there may be a few stiff bristles in the neigh-

Fig 67 The Porpoise *Phocæna communis*

bourhood of the mouth, but the lack of a protective external covering is fully compensated by the thickness of the skin and by the presence of a thick layer of fat (blubber) underneath it. A tail fin is present, but this, instead of being flattened from side to side, as in a fish, is flattened from above downwards. The fore limbs have been converted into paddles, presenting externally no trace of digits, and the hind limbs have disappeared, though traces of them are to be found on dissection. There may be one or two nostrils, situated, for convenience in breathing, on the top of the head. Cetacea feed on other animals, ranging from comparatively large forms to small creatures which are found in huge shoals.

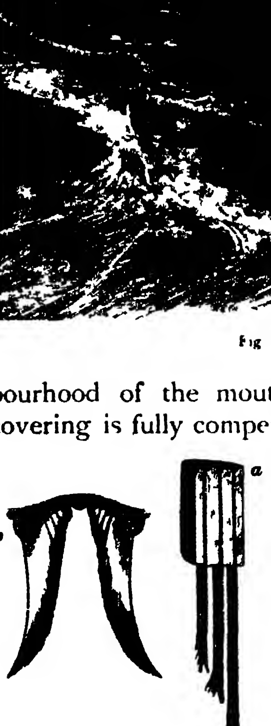


Fig 68 —Baleen in the Upper Jaw of Whale

a Section of a portion of the palate of a whalebone whale, showing three baleen plates *b*, The arrangement of the baleen plates on opposite sides of the jaw.

The Porpoise (*Phocæna communis*) (fig. 67), which possesses

numerous simple teeth, is a familiar British species, while the Greenland or Right Whale (*Balæna mysticetus*) is an example of the large toothless forms, which feed on shoals of minute marine organisms, from which the water is strained by numerous plates of whalebone (baleen) projecting downwards from the palate (fig. 68).

Order 7.—Sea-Cows (Sirenia)

This small order includes only two living genera of aquatic mammals, inhabiting the shores of the Atlantic and Indian Oceans,

Fig. 69.—The Manatee (*Manatus*)

and also making their way up some of the large rivers. As might be expected, considering their mode of life, they are shaped not unlike Cetaceans, with which they agree in the general shape of the body, absence of hind-limbs, and possession of a horizontally-flattened tail fin and flipper-like fore-limbs. They are not, however, quite so much specialized, for there is a fairly-well-marked

neck, and the nostrils are situated at the end of a broad muzzle, provided with thick fleshy lips beset with moustache hairs. There are also eyelashes, and the thick skin is covered with short stiff hairs. They subsist entirely on vegetable food, and simple grinding teeth are present in both genera. A pair of mammary glands are found on the breast.

The Dugong (*Halicore Dugong*) is 16 or 17 feet long, and frequents the shores of the Indian Ocean, while the somewhat smaller Manatee (*Manatus*) (fig. 69) is found on the west coast of Africa and the east coast of America, from the Gulf of Mexico southwards. A certain interest attaches to these creatures from the fact that they appear to be the chief foundation for legends of mermaids and mermen. It requires a pretty vivid imagination, however, to see any resemblance in these uncouth animals to the golden-haired conventionalities which have gradually been evolved from the inner consciousness of artist and poet.

Order 8.—Elephants (Proboscidea)

These familiar mammals, the largest of existing land animals, are in many respects primitive in structure, particularly as regards the limbs, which possess five digits, united together into flat rounded feet, provided with a varying number of small hoofs. The limbs are very thick and pillar-like, being thus enabled to support the enormous weight of the body. Elephants, however, are very highly specialized as regards the structure of the head, of which the most striking feature is the trunk, or prolonged snout, at the end of which the nostrils are situated. The uses of this remarkable organ are innumerable, and there can be no doubt that its development has led to a corresponding growth of intelligence. The teeth are highly peculiar, only two kinds, incisors and molars, being present. Of the former only an upper pair exists, modified in the male, or it may be in both sexes, into the well-known tusks, which are composed entirely of ivory or dentine (see p. 35). The molars are enormous, and possess broad grinding crowns, provided with numerous transverse ridges (fig. 70). For the most part only four are in place at once, one on each side

A B

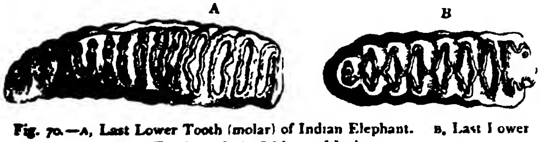


Fig. 70.—A, Last Lower Tooth (molar) of Indian Elephant. B, Last Lower Tooth (molar) of African Elephant

of either jaw, and they are replaced by others which grow from behind and gradually push out their predecessors as these get worn away. It is scarcely necessary to remark that in the vast majority of mammals teeth are succeeded by others which grow up vertically below them. The skull of an adult elephant is of remarkable form, and the cranium is much larger than the brain

Fig. 71.—African Elephant (*Elephas Africanus*). (From an instantaneous photograph)

which it contains, owing to the excessive development in its roof of air-chambers separated by complex bony plates. It may lastly be noted that the thick skin is but sparsely covered with hairs, and that the mammary glands are situated between the fore-limbs. The food consists exclusively of vegetable matter.

Elephants are now represented by only two species, one the Indian form (*Elephas Indicus*), found also in Ceylon, Borneo, and Sumatra, while the other (*Elephas Africanus*) is limited to Africa south of the Sahara (fig. 71).

Order 9.—Conies (Hyracoidea)

This small order includes only certain little creatures about the size of a rabbit, which inhabit the deserts of Africa and Syria. The general resemblance to a rabbit is seen chiefly in the cleft upper lip, and the presence of two long upper incisors which grow continuously, while canine teeth are entirely absent. In the

character of the cheek teeth, however, and in the nature of the digits they are much more like the tapir and rhinoceros. Each fore-foot has four toes, and each hind-foot three, all of which, except the innermost toe of the hind-foot, which is clawed, possess small rounded hoofs.

The "coney" of the English Bible, otherwise known as the Syrian Hyrax (*Procavia Syriaca*) may be taken as a type. "The

Fig. 72.—The Abyssinian Hyrax (*Procavia Abyssinica*).

conies are but a feeble folk, yet make they their houses in the rocks" (Prov. xxx. 26). The illustration (fig. 72) represents a similar species, the Abyssinian Hyrax (*P. Abyssinica*).

Order 10.—Hoofed Mammals (Ungulata)

This very large and important order includes animals in which the limbs are modified for the sole purpose of terrestrial progression, while the organization generally is adapted to the herbivorous habit, as more particularly seen in the grinding crowns possessed by the cheek teeth.

Two sub-orders are recognized: I. the Odd-toed Ungulates (Perissodactyla); and II. the Even-toed Ungulates (Artiodactyla)

I. Odd-toed Ungulates (Perissodactyla).—This sub-order embraces the three families of: 1. Tapirs, 2. Rhinoceroses, and 3. Horses, in all of which there is an odd number of toes on the hind-foot, and generally on the fore-foot as well. A much more important distinction, however, is found in the fact that the third

digit dominates over the rest and is symmetrical in itself, continuing the direction of the limb-axis.

1. The *Tapirs* in general appearance are not unlike large pigs, but the symmetry of the feet is quite different, and so is the number of the toes, there being four on the front, and three on the hind foot, all provided with hoofs. A pig has four toes on every foot. The snout is drawn out into a short proboscis, which

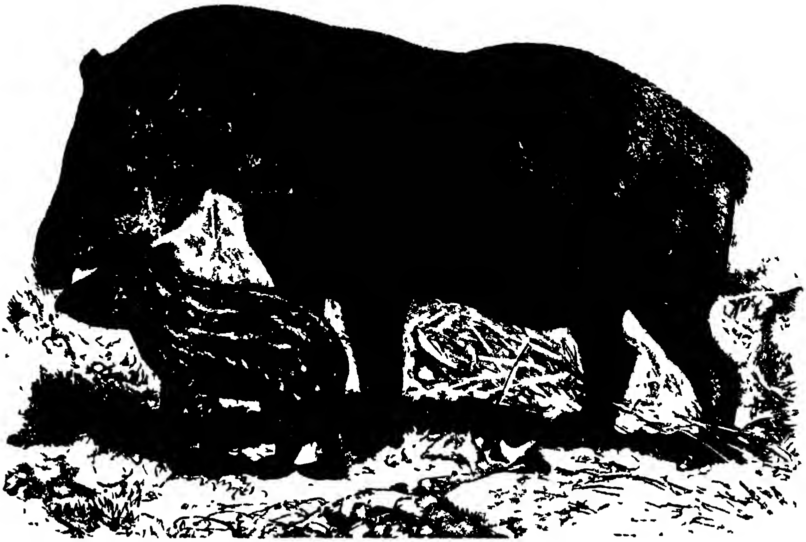


Fig. 73.—The Brazilian Tapir or Anta (*Tapirus Americanus*)

suggests what the incipient proboscis of the ancestors of elephants was probably like. Tapirs present a remarkable case of the phenomenon known as "discontinuous distribution", where a species or some larger group inhabits two or more areas more or less remote from one another, while it is absent from the intermediate space. In this instance the disconnected areas are South and Central America on the one hand, and the Malay region on the other. The species commonly seen in zoological gardens is the Brazilian Tapir (*Tapirus Americanus*) (fig. 73).

2. *Rhinoceroses* are huge clumsy-looking animals of little intelligence and surly disposition. The massive head, borne on a short thick neck, is characterized by its small eyes, oval erect ears, and one or two unpaired horns on the upper side of the snout. It is indeed the possession of such a horn which is the most

striking feature, giving the common name of the animal (Gk. *rhīnós*, of the nose; *kéras*, a horn), and it is probably responsible for the creation of the legendary unicorn. This defensive structure, when examined microscopically, is seen to be made up of innumerable horny fibres cemented together, and it has been aptly compared to a big wart, for there is no connection between it and the underlying bone. The African natives have a curious superstition that cups made from this horny material destroy the potency of any poisoned drink which may be poured into them.

Each one of the four extremities ends in three toes, provided with strong hoofs, there being thus a reduction in the fore foot as compared with tapirs. The skin is exceedingly thick and but scantily provided with hair, though there is a well marked tuft on the end of the short tail. The snout is not produced into a proboscis, but the upper lip is extremely flexible. The teeth are well adapted to a vegetable diet, for the grinders have broad crushing crowns of peculiar and characteristic pattern. Upper canines are absent, and sometimes lower ones too. There is much variability in regard to the front teeth, and in the adult these may be absent altogether.

The group is at the present time confined to South Asia and Tropical Africa, and typical species are the one-horned Indian Rhinoceros (*Rhinoceros Indicus*), in which the thick skin is disposed in remarkable armour-like folds, and the Common Rhinoceros (*Atelodus bicornis*) of Africa, the skin of which is relatively thin and devoid of folds, while there are two well-developed horns placed close together.

3. *Horses* and their immediate allies are decidedly the most highly specialized of the odd-toed Ungulates. All the living species belong to the single genus *Equus*, the external characters of which are too well known to need description. It may, however, be noted that the long legs, well suited for swift running, possess but one externally visible toe, corresponding to the middle one of five-toed forms, and provided with a rounded hoof. The front teeth are well developed, and each of them has a deep indentation in the crown, which gets filled up with fragments of the food, and is the cause of the black central area commonly known as the "mark". The canines are reduced and often absent in the female, but the cheek teeth are numerous, and their flattened crowns exhibit an exceedingly complex pattern.

THE INDIAN RHINOCEROS (*Rhinoceros Indicus*)

The living species of Rhinoceros are native only to Africa and South Asia, although, as shown by geological evidence, animals of the kind were once very widely distributed, and some of them inhabited prehistoric Britain The group is known to have originated in North America The common Indian species represented ranges from Bengal to Cochin China, and is the kind which figured in the gladiatorial displays of the ancient Romans It is distinguished by the possession of a single horn upon the nose, and armour like folds in the thick skin

THE INDIAN RHINOCEROS (RHINOCEROS INDICUS).

A STUDY FROM THE LIFE

The domesticated Horse (*Equus caballus*) has such a long history of captivity that its ancestry is obscure, and it is by no means certain that all horses have descended from one stock. It is, however, generally believed that one original stock was Asiatic, and perhaps the Tarpan or Wild Horse (*Equus tarpan*) of Central Asia comes nearest to this stock, though even that is far from being certain. *Wild Asses* are found both in Africa and Asia, and the domesticated form familiar to us comes nearest to an Asiatic species, the Onager (*Equus onager*), which ranges from Asia Minor to India. The domestic asses of Egypt and Abyssinia, however, more closely resemble the African Wild Ass (*Equus tæniopus*), native to the region between the Red Sea and Nile. The remaining living equines are those striped African species known as *Zebras* or *Tiger Horses*. The kind most commonly seen in zoological gardens is Burchell's Zebra (*Equus Burchelli*), herds of which are still to be found in the grassy plains to the north of the Orange River.

II. Even-toed Ungulates (Artiodactyla).—This large and important group of Ungulates includes not only many valuable domesticated forms, such as swine, oxen, goats, sheep, and camels, but such familiar types as hippopotamus, antelopes, llama, and giraffe. The even number of the toes is a character of far less importance than the symmetry of the foot, there being no single digit which is symmetrical in itself, like the third or middle one in the preceding group.

Two sections are recognized.—A. Non-ruminating forms, and B. Ruminants.

A. *Non-Ruminating Forms*

This includes, 1. the Hippopotamus Family, and 2. the Pig Family, in neither of which are the digestive organs modified for the purpose of ruminating or "chewing the cud". They belong, therefore, to the "unclean animals" of the Levitical law, despite their cloven feet (Lev. xi).

1. The *Hippopotamus Family* is entirely confined to the rivers of Africa, with the adjacent swampy ground, and is represented by two living species, *i.e.* the small Liberian Hippopotamus (*Hippopotamus Liberiensis*), limited, so far as known, to Liberia, and the Common Hippopotamus (*H. amphibius*), the large form frequently seen in captivity, which has a much wider range. The appearance

of this huge lumbering creature, which weighs about 2½ tons, suggests a parody on the pig, or a large barrel mounted on four stout ungainly legs. Each foot possesses four toes provided with rounded hoofs. The head is enormous, and the snout greatly swollen. The thick skin is almost devoid of hair, and is thrown into folds above the limbs. Those who have noticed a captive hippo open its tremendously wide mouth will have seen a truly terrific dentition displayed. Above are four peg-like incisors flanked by large canines, while below there are two huge cylindrical incisors, two smaller incisors, and formidable tusk-like canines (fig. 74). A full complement of grinding teeth is present, and the large molars, when their crowns are worn, exhibit a pattern resembling a double trefoil. The hippopotamus was well known to the ancients, and is the behemoth of Scripture.

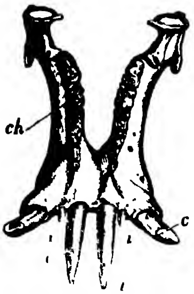


Fig. 74. Lower Jaw of Hippopotamus.
ch, The cheek teeth originally tuberculed, but worn down by use so as to present the appearance of clover leaves bordered by bands of enamel. *i*, incisors. *c*, canines.

2. The *Pig Family* has a wide distribution both in the Old and the New World. Well-marked features are the bristly skin, flexible snout tipped by a fleshy disc within which the nostrils open, teats extending right along the under side of the body, and legs of moderate length and thickness. There are four toes on each foot, the two central ones only reaching the ground, and being of relatively large size. The most illustrative type is the Wild Boar (*Sus scrofa*), once a native of Britain, and which at the present time ranges throughout Europe, Asia, and North Africa. It appears to be the original stock from which the domestic pig has been derived. The teeth are numerous and of primitive type, the points of greatest interest being the tusk-like canines, all four of which are upwardly directed, and the grinding teeth, which possess tuberculated crowns.

In Africa south of the Sahara the Wild Boar type is replaced by forms in which there are swellings on the face caused by underlying bony projections. These are comparatively small in the Red River-Hog (*Potamochœrus penicillatus*) of Guinea, which is further distinguished by a tuft of hair at the tip of each ear; but in the *Wart-Hogs* they are of large size, and give the enormous head a particularly forbidding appearance. There are two species, one (*Phacochœrus Æthiopicus*) being found at the Cape,

while the other (*Ph. Africanus*) is much more widely distributed.

In Celebes and the adjacent islands a remarkable pig is found known as the Babirussa (*Porcus babirussa*), in which the lower tusks are like curved daggers in shape, while the upper tusks curve back over the face almost like horns. The natives say that the animal hangs itself up by these when it wishes to sleep peacefully.

In America, from Mexico southwards, the pigs are represented by small forms called *Peccaries*, one species being the Collared Peccary (*Dicotyles torquatus*)

B. *Ruminants*

The members of this section agree with the pigs in possessing on each foot only two toes which reach the ground, in addition to which there may or may not be two smaller digits, but they differ markedly from pigs in the greater length of their limbs, which are eminently adapted for rapid progression. The most characteristic feature, however, is to be found in the possession of a very complex stomach, adapted for ruminating; *i.e.* the food is first swallowed without chewing, and then returned to the mouth in successive portions for leisurely mastication in a safe place. The cheek teeth have grinding crowns, provided with crescentic ridges, and (except in camels) the upper incisors are replaced by a hard pad. The following families together constitute the section: 1. Chevrotains; 2 Deer; 3. Prongbucks; 4. Oxen and their allies; 5. Giraffes; and 6. Camels.

1. The *Chevrotains* are a restricted group, including the smallest and least specialized ruminants, approaching the peccaries in some structural features. In appearance they suggest diminutive hornless deer, and on this account are sometimes called Mouse-Deer. There are no upper incisors, and the upper canines of the male are slender, downwardly-directed tusks. Of the six existing species five belong to the genus *Tragulus*, and are distributed through South Asia from India eastwards. The smallest species is the Malay Kanchil (*Tragulus Javanicus*) (fig. 75), than which only one other Ungulate, the Royal Antelope, is of less size. The sixth species of this family is the Water Chevrotain (*Dorcatherium aquaticum*), which is only found on the west coast of Africa.

2. The *Deer Family* includes a large number of species, widely distributed throughout both hemispheres, though absent from Africa south of the Sahara. There are four toes to each foot, all being provided with hoofs, but the supporting bones of the extremities are rather more specialized than in the Chevrotains. The leading characteristic of the family is undoubtedly the possession of antlers by the male in nearly all cases. These structures are essentially bony outgrowths from the skull which are annually shed, and in many cases become more complex in shape each successive year so as to be an indication of age. The young antlers are composed of living bone and are covered by a continuation of the skin ("the velvet"). When their full size is attained the base of the antler grows out into a ring-like projection (the "burr"), cutting off the blood-supply from the skin, which consequently peels off from the underlying bone, causing this to become dead and hard. A further characteristic of deer is the presence of a pit in front of each eye, within which certain glands open.

Fig. 75. The Kanchil (*Tragulus Javanicus*).

It is convenient to first mention the Musk Deer (*Moschus moschiferus*, because it differs considerably in structure from all other members of the group, having, *e.g.*, a less complex brain, and possessing a gall-bladder, which organ is absent in other deer. There are no antlers, and the upper canines of the male resemble those present in Chevrotains. Most of the musk of commerce is obtained from a pouch situated pretty far back on

the under side of the body in the male. Musk Deer are active creatures inhabiting the high land of Central Asia

The Chinese Water Deer (*Hydropotes inermis*), which lives on the banks of the Yang-tse-Kiang, shares with the preceding species the two primitive characters of tusk-like upper canines and absence of antlers in the male. This does not, however, indicate any special relationship between the two forms.

The Red Deer (*Cervus elaphus*) is still numbered among British mammals, though in the wild state it is now restricted to the remoter parts of Scotland and Ireland, with isolated patches in England. It is characterized by the complex antlers (fig. 76), which have a brow-tine projecting over the forehead, a bez-tine above this, and, in mature specimens, a terminal cluster of twelve or more points. Outside Britain this species has a wide distribution through the temperate parts of Europe and Asia.

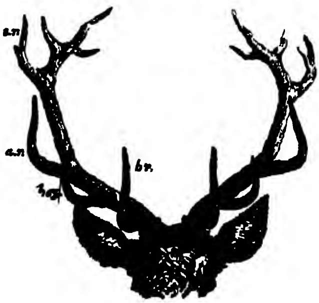


Fig 76 —Antlers of Red Deer
br Brow tine *bez* bez tine *a r* antler royal *s r* sur royal.

The large Wapiti (so-called "Elk") of North America (*Cervus Canadensis*) is closely allied to the Red Deer. Ranging at one time over most of North America, it is now restricted to the mountainous parts of the Western States and to British territory in the north.

The familiar Fallow Deer (*Cervus dama*) is not a native of these islands, though introduced at an early date, but is indigenous to the Mediterranean countries. It is much smaller than the Red Deer, and the antlers are of different formation. They are said to be "palmated", *i.e.* ending in a broad expansion divided into points, and compared to a hand with its fingers. Below this expanded portion is a branch called the trez-tine, and a good way below this a prominent brow-tine juts out.

Great interest attaches to the Reindeer (*Rangifer tarandus*) for several reasons, one being their great importance to certain primitive peoples as domestic animals. At the present time they are limited to the northern parts of both hemispheres, but in prehistoric times, when the climate of the northern hemisphere was much more rigorous than now, their range extended much farther south, as evidenced by remains found in the

caves of Britain and other countries. Indeed they were so characteristic of a stage in human history, when carefully-chipped stone weapons and implements had replaced the cruder attempts in this direction, that the term "Reindeer Age" is often applied to the period in question. A marked peculiarity is the presence of antlers in both sexes, these structures being of great length and set on far back. There is a brow-tine, greatly developed and branched in the male, just above this a bez-tine, and then a long beam, the end of which is palmated. The two antlers are commonly markedly unlike one another. The main hoofs are very broad and flat, and separate when the feet are brought to the ground, afterwards clapping together in a curious way when the feet are raised.

The largest living species of deer is the Elk or Moose (*Alces machlis*), the distribution of which roughly corresponds to that of the reindeer, though it does not range into those extreme northerly regions from which trees are absent. The long head terminates in a muzzle of curious humped appearance, suggesting a Roman nose; the neck is short, and the body slopes markedly from front to rear. The long legs are provided with broad hoofs. Many peculiarities are presented by the massive antlers, which, beginning with short beams devoid of tines, expand laterally into broad palmated portions. A curious feature of the male is the presence of a flap of skin hanging down from the under side of the neck.

The remaining species of which space permits a mention is the little Roe Deer (*Capreolus caprea*), our second native form, though now only found in Scotland as a truly wild animal. From Britain it ranges east through Europe into Persia. The rough antlers are of simple conformation. The beam rises vertically from the top of the head, gives off a front tine about the middle of its length, and then curves back to end in a simple fork.

3. The *Prongbuck Family* contains only the single species (*Antilocapra Americana*), to which it owes its name (fig. 77). It is a small active animal found in the temperate parts of western North America. Although in appearance suggesting a deer, its affinities are rather with the antelope section of the family of oxen. The horns, however, present a remarkable peculiarity, for though they consist of bony cores covered by horny sheaths, as in an

antelope, they are shed annually, which is not the case with the last-named form, and a further difference is seen in the presence of a small front branch. The two peculiarities mentioned

Fig. 77—The Prongbuck (*Antilocapra Americana*)

suggest antlers, but otherwise there is no reason for classifying Prongbucks with the deer

4. The *Ox Family* is an exceedingly large one, including those forms which are commonly known as hollow-horned ruminants (Cavicornia), because the unbranched horns, which are never shed, consist of hollow horny sheaths borne upon bony outgrowths from the skull. They may be present in both sexes, or else restricted to the male. The upper incisors and also the canines are absent, their place being taken by a horny pad against which the lower front teeth bite, as in deer, prong-bucks, and giraffes. The feet are much like those of deer, each possessing two large toes shod

with hoofs, two other toes being commonly represented by small hoofs, though these may be in this case absent altogether. The family not only includes (1) oxen in the widest sense, but also (2) sheep, (3) goats, and (4) antelopes. With but few exceptions, these are found only in the Old World.

(1) As in the case of so many other domesticated forms, there is considerable doubt as to the ancestry of European *oxen* (*Bos taurus*), but there can be little doubt that these are largely descended from the Auroch or Urus (*Bos primigenius*), which was hunted by prehistoric man and existed as a wild species so late as the twelfth century, though they are now known only as half wild cattle of comparatively small size, the best known of these being the herd preserved at Chillingham in Northumberland. In this case the muzzles and ears are red (though at an earlier date they were black), while the rest of the body is white.

A different origin must be sought for the *humped cattle* of Africa and India, the latter often receiving the name of Zebu (*Bos indicus*). It has been claimed that these are descended from an African stock, though this is only conjectural, and it may be observed that there are several wild species of Asiatic oxen which exhibit the humped character to a greater or less degree. This is the case, for example, with the Gaur (*Bos gaurus*) of India and Further India, to which the name ' bison " is often misapplied, and the Yak (*Bos grunniens*) of Thibet, distinguished by its long hair and horse-like tail.

The group of *Bisons*, to which in some respects the Yak approximates, are distinguished by several special features, among the most striking of which are the great disproportionate height of the front part of the body and the projection of the back of the head above the origin of the horns. The European Bison (*Bos bonassus*), once abundant, is now practically restricted to Lithuania and the Caucasus, and appears doomed to extinction, like the American Bison (*Bos Americanus*) (fig. 78), which existed in countless herds at no very remote period. Under the name of "buffalo" this animal plays a large part in various kinds of literature dealing with North America.

Buffaloes, using the term in the strict sense, are stoutly-built oxen with broad snout, strong thick horns, and large fringed ears set on rather far down. The hair is comparatively coarse and scanty, and the long tail is tufted. The group is characteristic

of the warmer parts of the Old World, and the most powerful species is the Cape Buffalo (*Bos caffer*), which has a wide distribution in Africa. While in this form the broad bases of the horns meet together in the middle, the long backwardly-directed horns of the much smaller Indian Buffalo (*Bos bubalus*) are separated by a wide interspace. As a wild animal it is confined to

Fig 78—The American Bison (*Bos Americanus*) (From an instantaneous photograph

India, but in the domesticated condition has a wide distribution through south-east Asia, and has also been introduced into Asia Minor, Egypt, and Italy.

The Musk Ox (*Ovibos moschatus*) (fig. 79) with its ram-like horns is more of the nature of a sheep than an ox. At the present time it is restricted to the arctic parts of the western hemisphere, and it is remarkable that so large a creature is able to find a sufficiency of vegetable food in such inhospitable wilds. Its name is due to the peculiar musky flavour which the flesh possesses

(2) *Sheep* resemble oxen in many respects but are much smaller animals, and the neck bends sharply up, so that the head

is carried comparatively high. Although in many wild forms horns are present in both sexes, those of the male are specially characteristic. Their form is more or less spiral, with the tips turned outwards; they are triangular in section, and marked by numerous transverse wrinklings. The snout is pointed, and there is usually a glandular pit below the eye, the tail is short, and a

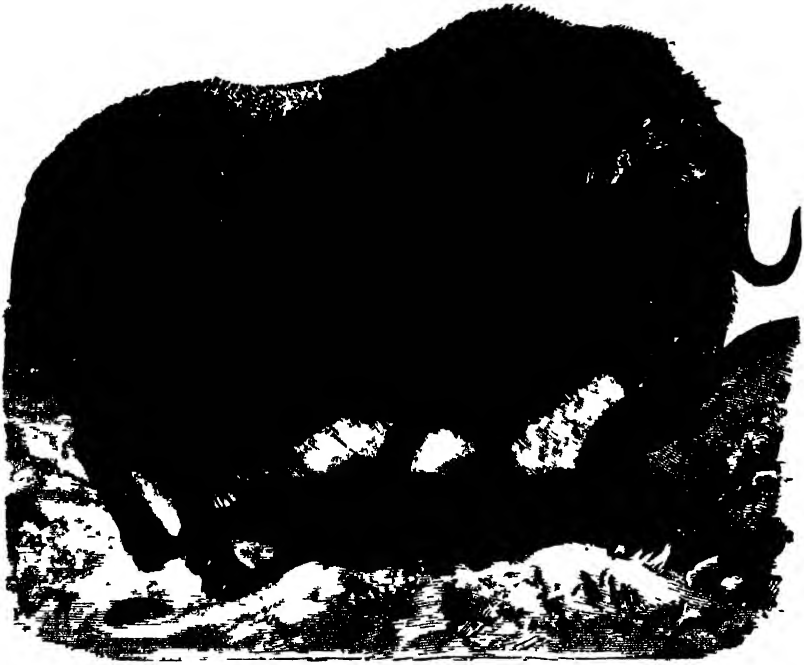


Fig 79 – The Musk Ox (*Ovibos moschatus*

bottle-shaped gland opens between the central toes of each foot. Of the eleven existing wild species nine inhabit the mountainous parts of Europe and Asia north of the Himalayas, while the remaining three belong respectively to North-west India, North Africa, and North America. The Bighorn (*Ovis Canadensis*) and Mouflon (*O. musimon*) may be taken as illustrations. The former ranges through the mountains of western North America from Alaska to Mexico, while the latter is at the present time only found in Corsica and Sardinia.

The same doubt attaches to the origin of tame sheep, which

have been domesticated from prehistoric times as to that of most other farm animals

(3) *Goats* agree with sheep in many respects but in typical cases are distinguished by the concavity of the face, peculiar hard patches on the knees, absence of glandular pits below the eye and lack of hoof glands in the hind-feet The male is characterized by a peculiarly unpleasant odour, strong backwardly curved horns, often with a corrugated surface, and a tuft of hair on the chin The group is essentially characteristic of the mountainous axis of the Old World from Spain eastwards to Thibet and North China but outlying species occur in South India Africa, and North America The species known as the Bezoar Goat or Grecian Ibex (*Capra ægagra*) which ranges from some of the Greek islands eastwards to Persia where it is called the pasang is interesting as being probably the chief stock from which the Domestic Goat (*Capra hirca*) is derived Goats are known to have been tamed from very early times and Homer in describing those of the Cyclops was no doubt alluding to this particular species which formerly had a much wider range in Greece

Among other species may be mentioned the Spanish Ibex or Wild Goat (*Capra Pyrenaica*) the almost extinct Alpine Ibex (*C ibex*) the Himalayan Ibex (*C Sibirica*) and the Arabian Ibex (*C Sinaitica*) The solitary American species is the Rocky Mountain Goat (*Haplocerus montanus*) which ranges through the Rocky Mountains from California to Canada It is not a very typical goat and forms one of a small group of genera intermediate in character between goats and antelopes

(4) *Antelopes* constitute a large group of hollow horned ruminants difficult if not impossible to define but including those members of the family which are obviously neither oxen sheep nor goats There are, however, many transitional forms such as the one last mentioned under the heading of goats The group is now characteristic of Africa, Syria, and Arabia, though there are a number of outlying species A typical antelope is elegant in form with head carried well above the body and bearing graceful horns, prominently ringed, and straight, simply curved or twisted The bony horn-cores are of more solid nature than in the other divisions of the ox family and there is frequently, as in sheep a glandular pit below the eye

The Chamois (*Rupicapra tragus*) is one of the transition forms

between goats and antelopes, so that it may be placed indifferently in either of them. It ranges from the Pyrenees to the Caucasus, and is the only animal in West Europe which has any claim to the name of antelope. A characteristic feature is seen in the sharp hook-like termination of the short black horns.

Among the most graceful members of the group are the small desert forms which, under the name of *Gazelles*, have been immor-

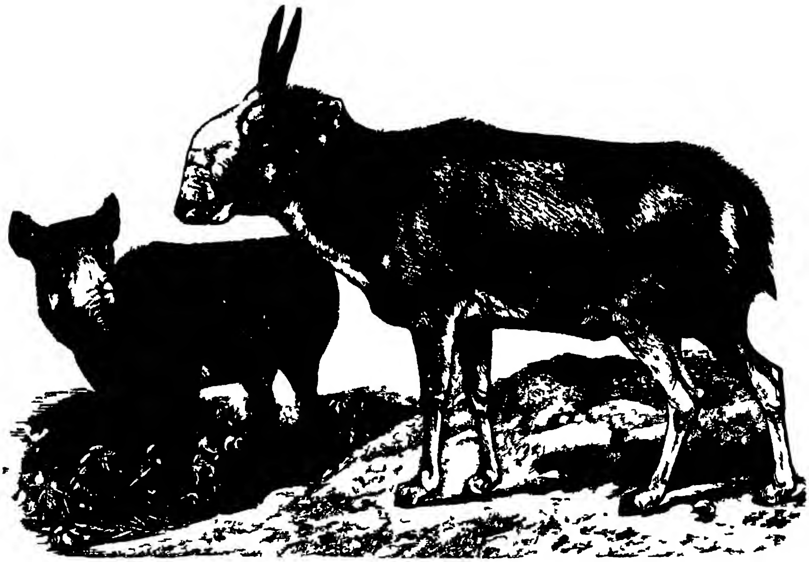


Fig. 80. The Saiga Antelope (*Colus Tartaricus*)

talized by various poets. The Dorcas Gazelle (*Gazella dorcas*), which inhabits North Africa, Syria, and Asia Minor, is perhaps the best known kind. Other species are the Persian Gazelle (*G. subgutturosa*), the Indian Gazelle (*G. Bennetti*), and the Arabian Gazelle (*G. Arabica*).

Probably the most remarkable looking antelopes are the Saiga Antelope (*Colus Tartaricus*) and the Wildebeest or Gnu (*Catoblepas gnu*). The former, which looks as if it suffered from badly-swollen face (fig. 80), ranges from the steppes of Russia-in-Europe to the Altai Mountains. Apart from the Chamois it is the only European antelope. The Gnu (fig. 81) is an inhabitant of South Africa, and looks like a mixture of buffalo and horse, being endowed with the head of the one and the tail of the other.

5. The *Giraffe Family* includes the Okapi (*Okapia Johnstoni*, see vol. ii, p. 170), and the Giraffe (*Giraffa camelopardalis*). The latter is found in desert and semi-desert regions to the south of the Sahara. The more familiar South African variety (fig. 82) is marked with conspicuous brown blotches upon a tawny back-

Fig. 81.—The Wildebeest or White-tailed Gnu (*Catoblepas gnu*).

ground, and this, suggesting the markings of a leopard, has given rise to the alternative name of Camelopard by which the animal is often known. In the variety living farther north the colours are reversed, so to speak, the background being brown, but the tawny hue is disposed not in patches but a close network of lines. Unfortunately, it appears to be one of the many species doomed to complete extinction at no distant date.

The giraffe rejoices in the distinction of being the tallest living mammal, adult bulls sometimes measuring as much 19 feet from the top of the head downwards. This unusual height is partly due to the great length of the neck, and partly to the relatively

greater height of the front part of the body. The head is decidedly graceful, the long tail is tufted, and there is no trace of accessory hoofs at the sides of the feet. As in sheep, &c., the upper incisors and canines are replaced by a horny pad. A very distinctive external feature consists in the possession of two short rounded horns, consisting of a bony core covered by soft skin. There is also a rounded skin-covered knob between the eyes.

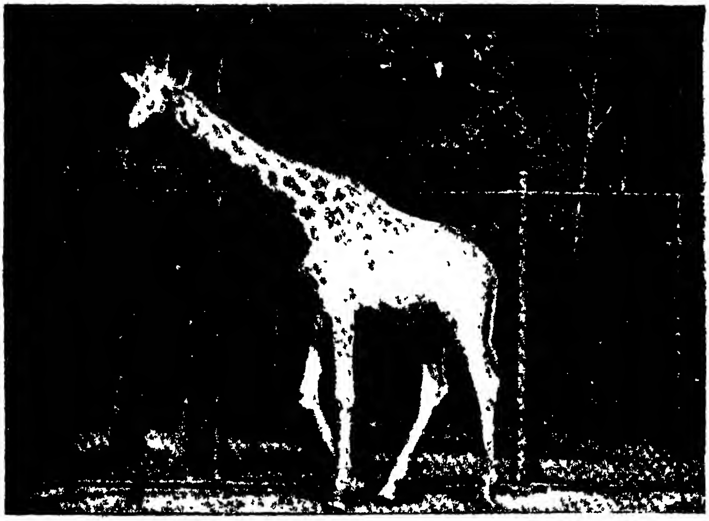


Fig. 52.—The Giraffe (*Giraffa camelopardalis*). (From an instantaneous photograph.)

The protrusible tongue is extremely flexible, and serves as a grasping organ for seizing the twigs of trees.

6. The *Camel Family* is the last to be mentioned under the heading of Ruminants. The head is devoid of horns and placed at the end of a long curved neck. The limbs are elongated, and each of them terminates in two toes only, while the hoofs are replaced by pad-like swellings on the under side of the foot. Further characteristics are the split upper lip, incisors in the upper jaw, and well-developed canines both above and below. The family includes the camels of the Old World, and the llamas, with allied forms, in the New World.

Camels, which are now unknown as wild animals, though admittedly invaluable domestic forms, are decidedly ugly if measured by our standards of good looks; nor do they make up by amiability

what they lack in beauty. Kipling's faithful delineation of the "gawd-forsaken oont" is too well known to need quotation, but the following vivid account of the purchase of a camel given by Conan Doyle (*Daily News* of April 21, 1896) is probably less familiar.

"There are camels to be bought, and it is a study in Eastern ways to see the *Daily News* buying them. Some men have the gift of pantomime, and some have not. I know by experience that I have not. On the occasion of an eclipse of the moon I endeavoured to explain the cause of it by gesture to an Arab. I pointed to the moon and to the earth. Then I pointed to a horse and to his shadow. Presently the Arab rose and began to examine the horse's hind-legs, and I found that I had convinced him that the creature was ill. I have given up gestures since then. But the *Daily News* has all the Arab's energy of movement, with a good command of abuse, and some powers as a pedestrian. With these gifts, one may buy camels.

"Having looked depreciatingly at the beast—and you cannot take a better model than the creature's own expression as it looks at you—you ask how much is wanted for it. The owner says sixteen pounds. You then give a shriek of derision, sweep your arm across as if to wave him and his camel out of your sight for ever, and, turning with a whisk, you set off rapidly in the other direction. How far you go depends upon the price asked. If it is really very high, you may not get back for your dinner. But as a rule, a hundred yards or so meet the case, and you shape your course so as to reach the camel and its owner. You stop in front of them and look at them with a disinterested and surprised expression, to intimate that you wonder that they should still be loitering there. The Arab asks how much you will give. You answer eight pounds. Then it is his turn to scream, whisk round, and do his hundred yards, his absurd chattel with his hornpipe legs trotting along behind him. But he returns to say that he will take fourteen, and off you go again with a howl and a wave. So the bargaining goes on, the circles continually shortening, until you have settled upon the middle price. But it is only when you have bought your camel that your troubles begin. It is the strangest and most deceptive creature in the world. Its appearance is so staid and respectable that you cannot give it credit for the black villainy that lurks within. It approaches you with

a mildly interested but superior expression, like a patrician lady in a Sunday-school. You feel that a pair of glasses at the end of a fan is the one thing lacking. Then it puts its lips gently forward, with a far-away look in its eyes, and you have just time to say 'The pretty dear is going to kiss me', when two rows of frightful green teeth clash in front of you, and you give such a backward jump as you could never have hoped at your age to accomplish. When once the veil is dropped, anything more demoniacal than the face of a camel cannot be conceived. No kindness and no length of ownership seems to make them friendly. And yet you must make allowances for a creature which can carry 600 lbs. for twenty miles a day, and ask for no water and little food at the end of it."

The Arabian Camel (*Camelus dromedarius*) is the common one-humped form of Africa and Asia, while the two-humped Bactrian Camel (*C. bactrianus*), a smaller animal, is characteristic of the desert regions of Central Asia.

The American members of the Camel Family consist of two wild species, conveniently grouped under the head of *Llamas*, a term also including the two domesticated forms. These animals are smaller than camels and more gracefully built; they are also devoid of a hump. The ears are pointed and comparatively long, instead of being short and rounded, the tail is very short, and the feet are relatively small as compared with the camel.

Of the two wild species the animal known as the Guanaco (*Lama guanacus*) is larger and more heavily built. It ranges .om the mountains of Ecuador southwards to Tierra del Fuego. It is probably from this species that the two domestic forms, known as the Llama (*L. lama*) and the Alpaca (*L. pacos*), are descended.

The second wild species is the comparatively small and graceful Vicunia (*L. vicunia*), which ranges through the mountains of South America from Bolivia to Ecuador.

Order 11.—Gnawers (Rodentia)

This widely-distributed order includes a larger number of forms than any other, all of which feed largely, and the majority entirely, upon vegetable food. The largest species does not exceed the size of a small pig, while some are extremely small. Most of

THE LLAMA (*Lama lama*)

This animal was domesticated in very remote times by the ancient Peruvians, and even now is an important beast of burden in the high Andes of Peru and Bolivia, though the original breed has been replaced to a great extent by domesticated forms introduced from the Old World. In former times it was used in great numbers for the transport of silver ore from the famous mines of Potosi in Bolivia, more than 13,000 feet above the sea.

The Llama may be described as an American cousin of the Camel, belonging, as it does, to the same group (*Tylopoda*) of Ruminants or Cud chewers. The earliest known members of this group were, however, native to North America, from which area the stock spread on the one hand into South America, and on the other into the Old World, having since become extinct elsewhere.

PERUVIAN LLAMAS (LAMA LAMA)

A STUDY FROM THE LIFE

them live upon the surface of the ground, but some burrow and some climb, while others have taken to the water. The general organization is of rather a low type, but there is much specialization in the most characteristic structures, *i.e.* the teeth. Rodents walk entirely or partly upon the soles of the feet, and the digits are usually provided with claws, though more rarely they possess small hoofs. The most striking feature regarding the teeth is the character of the incisors, of which in the adult never more than four are developed to a useful extent. These are large chisel-ended structures, growing continuously throughout life, as they are worn away by the constant gnawing which is so characteristic of the order. This is strikingly seen in the cases of unfortunate animals which have lost one incisor, as a result of which the corresponding tooth has nothing to bite against, and not being therefore subjected to wear, grows to an enormous length, ultimately killing its unlucky owner. A similar state of things may result from malformation or accident if thereby the upper and lower teeth are prevented from coming together. Canine teeth are always absent, and the cheek teeth are commonly reduced in number, and more or less adapted to act as grinders. There is an interesting feature, already alluded to (p. 28), regarding the jaw-joint, which permits of the free backward and-forward movement necessary for gnawing. This is due to the fact that the condyles of the lower jaw are elongated from front to back, and fit into sockets of corresponding shape.

Fig. 83.—Skull of Hare. Observe the small upper incisors *i'* behind the large functional ones *i*. *c.p.* coronoid process, *z.a.* zygomatic arch.

There are four great groups of existing Rodents, which may broadly be called: 1. Rabbits; 2. Squirrels; 3. Mice; and 4. Porcupines.

1. The group of RABBITS, including also Hares and Pikas, is distinguished by the presence of two small upper incisor teeth, situated immediately behind the two large teeth of the same kind present here as in all Rodents (fig. 83). It may also be added that the two bones of the lower

leg (tibia and fibula) are united together at their lower ends. Three animals common in Britain may be taken as illustrations, *i.e.* the Rabbit, Hare, and Alpine Hare.

The Rabbit (*Lepus cuniculus*) (fig. 84), though so common in the British area, is believed not to be indigenous, and the same may be said of many other countries where it now abounds. Its

Fig. 84.—The Rabbit (*Lepus cuniculus*)

original home was probably in the area adjoining either shore of the western Mediterranean. Marked characteristics are gregariousness, burrowing habits, and the immature state in which the young are born. The Hare (*L. timidus*) is a larger animal which is not gregarious and does not burrow, while the newly-born leverets can see, and are scantily clad with fur. The black-tipped ears and very long hind-limbs are also noticeable features. Absent from Ireland, Scandinavia, and North Russia, the hare has a wide distribution over the rest of Europe from Great Britain to the Caucasus. The Alpine Hare (*L. variabilis*) assumes a white or light-coloured winter coat. In the British area it is found in Scotland and the northern parts of England, while it replaces the common species in Ireland. From our islands it ranges across the northern part of the Old World to

Japan, and also from the Pyrenees to the Caucasus. Other species of hare are found in various parts of Asia, Africa, North America, and South America.

Pikas, or *Calling Hares*, are small creatures somewhat resembling guinea-pigs, apparently devoid of tail, and with rounded ears of small dimensions. They are gregarious, and, failing fissures in the rocks, excavate burrows. Most of the species inhabit the north and central parts of Asia, one of these, the Siberian Pika (*Lagomys Alpinus*) (fig. 85) ranging into Eastern Europe. There is also one species in North America.

Fig 85.—The Siberian Pika *Lagomys Alpinus*

The three remaining groups of Rodents, Squirrels, Mice, and Porcupines, agree with one another, and differ from rabbits and their allies, in the number of the incisor teeth, these being only four in number, two above and two below.

2. The SQUIRRELS include forms in which the bones of the lower leg (tibia and fibula) are not united together. Squirrels, Marmots, and Beavers are the representative types.

SQUIRRELS, as well seen in the Common Squirrel (*Sciurus vulgaris*), our native species, have a rounded head, from which large tufted ears project, a large bushy tail, and extremities provided with sharp claws. The thumb is of very small size. The range of this species includes the greater part of Europe, North and Central Asia, and North Africa. Squirrels of one sort or another are found in almost all hot and temperate countries, Madagascar and Australia excepted. *Ground-Squirrels*,

which, as the name indicates, live upon the ground, are common in the colder parts of the northern hemisphere. Much resembling ordinary squirrels in appearance, they differ in the smaller size of the tail, the absence of tufts to the ears, and the possession of large cheek-pouches. They excavate burrows in the ground. The Common Chipmunk (*Tamias striata*) of North America is a good example. *Flying-Squirrels* possess a parachute-like fold of skin on either side, much as in the Flying-Lemur (cp p. 86). They mostly range from India to Japan, but are also represented in North America Siberia, and East Europe. The Brown Flying-Squirrel (*Pteromys petaurista*) is the largest species. The African Flying-Squirrels (*Anomalurus*), mostly natives of West Africa, differ from the preceding chiefly in the structure of the tail and flying membrane.

Fig. 86.—The Common Suslik (*Spermophilus citillus*).

Least squirrel-like of the squirrel sub-group are the *Susliks* or *Gophers*, found in much the same regions as the ground squirrels. They are burrowing forms with large cheek-pouches. The Common Suslik (*Spermophilus citillus*), which ranges from Central Europe to Siberia, has a short tail and very small ears (fig. 86). The Striped Gopher (*S. tridecemlineatus*) of North America is somewhat better off as regards ears and tail, and is prettily marked with stripes and rows of dots.

MARMOTS are more stoutly built than squirrels, their ears being smaller and their tails shorter, while cheek-pouches are present. They are burrowing social forms, and their area of distribution includes the colder parts of the northern hemisphere. A familiar European type is the Alpine Marmot (*Arctomys marmotta*) of the Pyrenees, Alps, and Carpathians. A common North American form is the Woodchuck (*Arctomys monax*).

The *Prairie Marmots* of North America are closely related to the preceding. The best-known species is the Common Prairie Marmot, often called "prairie-dog" (*Cynomys ludovicianus*), large

numbers of which inhabit the plains on the east of the Rocky Mountains (fig. 87).

BEAVERS are comparatively large Rodents which spend a large part of their time in the water and are modified accordingly, the hind-feet being webbed, and the rudder-like tail flattened and scaly. There are only two living species, one in Eurasia and the other in North America. The former, or European Beaver

Fig. 87.—Prairie Dogs (*Cynomys ludovicianus*).

(*Castor fiber*), at present ranges from France to Siberia but was once distributed much more widely, and in remoter times was a member of the British fauna, as attested by numerous remains. The American Beaver (*Castor Canadensis*) is now practically limited to Canada, though it once extended over the greater part of North America.

3. MICE include a very large number of species, and are represented in all parts of the world. A characteristic anatomical feature is found in the union of the two bones of the lower leg (tibia and fibula). The group includes the following families:—(1) Mice and Rats; (2) Mole-Rats; (3) Pouched Rats; (4) Jumping-Mice; and (5) Dormice.

(1) The *Mouse and Rat Family* includes more species than the others, and unlike them is cosmopolitan, being represented

even in Australia, from which all the other groups are absent. The tail is bare and scaly, the incisor teeth narrow, and the fore- and hind-limbs of about the same length. The thumb is much reduced. No less than eight species are found in Britain including rats, mice, and voles. The largest of these is the Common or Brown Rat (*Mus decumanus*), which, like all members of the same genus, has a long tail, and projecting tubercles on the crowns of the grinding teeth. It is supposed to have been introduced in the year 1730, and has largely ousted the smaller Black Rat (*M. rattus*), which is also an introduced form though the date of its first arrival was much more remote. The most familiar of our mice is the House Mouse (*M. musculus*), distinguished by the large size of its delicate ears. The Wood Mouse, also called the Long-tailed Field-Mouse (*M. sylvaticus*), is very similar in appearance, but can be distinguished by its white under-surface. The little Harvest-Mouse (*M. minutus*), the nests of which are often found suspended from corn-stalks, is the most diminutive of our native mammals, the smallest shrew alone excepted. ***Voles***, of which three species are native to Britain (but not Ireland), are distinguished from rats and mice by their clumsier proportions, shorter limbs and tail, and blunter snouts. They feed entirely upon vegetable matter, their back teeth being adapted to this kind of food, and having crowns of peculiar

Fig. 88 The Water Vole (*Microtus amphibius*)

pattern, suggesting a double series of opposed triangles alternating with one another. The largest of our three species is the Water-Vole (*Microtus amphibius*), often miscalled the Water "Rat". It is brown in colour and about the same size as an ordinary brown rat (fig. 88). The Bank-Vole (*M. glareolus*) is less stoutly built, with redder fur and longer tail. Much smaller and more abundant than these two species is the Field-Vole (*M. agrestis*), which sometimes multiplies to such an extent as to become a serious agricultural pest. It is often called the Short-tailed Field-Mouse, but is at once distinguished from a mouse by its shorter tail, and by the other features already enumerated as characteristic of voles generally.

Fig. 89. The Lemming (*Myodes lemmus*)

Other examples of the Mouse family are afforded by the *Hamsters*, *Lemmings*, and *Musquashes*. The Common Hamster (*Cricetus frumentarius*) of Europe and North Asia is a comparatively large rodent, being as much as a foot in length inclusive of the short tail, the abbreviated nature of which at once shows that the creature is not a rat, which animal it otherwise somewhat resembles in external appearance. There are very large cheek-pouches. Hamsters are burrowing forms, and they store up large quantities of grain, seed, and other vegetable matter. They increase very rapidly in number and often do serious damage to crops. "A South American relative (*Ichthyomys*) of the Hamster lives in

streams, and feeds on fish The edges of the upper incisors are slanted towards each other to give a Λ shaped notch This is an adaptation for holding the slippery prey"

Lemmings resemble voles in many respects, but their tails are even shorter while their claws are better developed and the fur is much thicker The best known species is the Norwegian Lemming (*Myodes lemmus*) (fig 89) which inhabits the mountain regions of Scandinavia and from time to time migrates in vast numbers travelling in a straight line despite all obstacles and ultimately plunging into the sea where it soon perishes as might be anticipated

Fig 90 Kangaroo Rat *Dipodomys phillipsi*

The Musquash or Musk Rat (*Fiber zibethicus*) which has a wide range in North America may be regarded as a very large vole thoroughly adapted to an aquatic life as may be seen by its partly webbed feet and strong flattened tail It is largely hunted for the sake of its fur

(2) The *Mole-Rat Family* includes Old World rodents which have taken to a burrowing life, with the result that their structure has undergone modifications of much the same kind as those exemplified by ordinary moles A typical species is the Great Mole Rat (*Spalax typhlus*), the range of which includes South-east Europe, South-west Asia, and lower Egypt

(3) The North American *Pouched-Rat Family* includes a

number of forms which, though they differ greatly among themselves in appearance, all possess large hair-lined cheek-pouches. The Common Pocket-Gopher (*Geomys bursarius*) looks something like a compromise between a rat and a mole. It is a burrowing form inhabiting the central plains watered by the Mississippi and its tributaries. The Common Kangaroo-Rat (*Dipodomys Phillipsi*) is a desert animal with long hind-limbs and tail (fig. 90), enabling it to adopt the mode of progression characteristic of the kangaroo. The Banded Pocket-Mouse (*Perognathus fasciatus*) of the States resembles the last-named form on a small scale.

(4) The *Jumping-Mouse* or *Jerboa Family* includes species which, like the Kangaroo-Rat and Pocket-Mouse of the last family, are specialized in relation to a springing mode of progression. They are, however, devoid of cheek-pouches. The species are chiefly found in Africa and Asia, though the family is also represented in South Europe and North America. A good illustrative species is the Siberian Jerboa (*Alactaga decumana*) (fig. 91).


Fig 91.—The Jerboa (*Alactaga decumana*)

(5) The *Dormouse Family* embraces small mouse-like animals which have adopted an arboreal life, and in some respects have become specialized in much the same way as squirrels. Species are found in Europe, Asia, and Africa, and there is one British form, the Common Dormouse (*Muscardinus avellanarius*), abundant in the south of England, but absent from Ireland and the northern part of Great Britain (fig. 92).

4. The PORCUPINE group of Rodents takes in a large number of forms, of which one common character is the separateness of the two bones (tibia and fibula) of the lower leg. The group is predominatingly American, and specially characteristic of South America. The following five families are included:—(1) Octodons; (2) Porcupines; (3) Chinchillas; (4) Agoutis; and (5) Cavie

(1) *Octodons* are somewhat rat-like forms mostly found in

South America, but also represented in the West Indies and in Africa. A typical form is the Degu (*Octodon degus*) of Peru and Chili (fig. 93). The enamel folds on the crowns of the grinding teeth have a characteristic figure-of-eight pattern.

Fig. 92.—The Common Dormouse (*Muscardinus avellanarius*)

(2) The *Porcupine Family*, distinguished by the possession of quills, is very widely distributed, Australia being the only continent from which its members are absent. All the Old World forms live on the ground, as is, for example, the case with the Common Porcupine (*Hystrix cristata*), which inhabits the Mediterranean countries, though comparatively scarce in those of them which are European. The Brush-tailed Porcupine (*Atherura Africana*) of West and Central Africa looks like a spiny rat. The New World forms are distinguished by being climbers. A common example is the Canadian Porcupine (*Erethizon dorsatus*).

None of the remaining families of the Porcupine group are

found outside South America, Central America, and the West Indies.

(3) The family made up of the *Chinchillas* and their allies is distinguished by the soft fur, well-developed tail, elongated hind-legs, and transversely-ridged crowns to the grinding teeth. The Common Chinchilla (*Chinchilla lanigera*) (fig. 94), a valuable

Fig. 93.—The Degu (*Octodon degus*)

fur-bearing animal inhabiting the mountains of Chili and Bolivia, is a very active squirrel-like creature in which there are five toes on the fore- and four toes on the hind-foot. The allied Viscacha (*Lagostomus trichodactylus*) is a stoutly-built burrowing form, of which the communities are common in the pampas of South America.

(4) The *Agoutis* and *Pacas* together constitute a South American family of which the members attain a considerable size. The claws are blunt and hoof-like. The short-tailed Common Agouti (*Dasyprocta agouti*) inhabits the forest regions of South America, and the tailless Paca (*Cœlogenys paca*), distinguished

by the presence of five rows of yellow spots on the fur, has a wide range through the same continent, east of the Andes and to as far south as Paraguay. It is also a native of the islands of Trinadad and Tobago.

(5) The family of *Cavies* resembles the preceding in the hoof-like nature of the claws, and are further characterized by the

Fig 94 The Common Chinchilla (*Chinchilla lanigera*)

extreme brevity of the tail. The grinding teeth are complex, and their crowns present numerous transverse ridges A common example is the domestic Guinea-Pig (? *Guiana pig*), introduced into Europe in the sixteenth century. The Restless Cavy (*Cavius porcellus*) of Uruguay and Brazil has been claimed as the ancestral stock, though the view is now held that this distinction rests with Cutler's Cavy (*Cavia Cutleri*), a Peruvian form supposed to have been domesticated by the Incas. The largest known Rodent, the Capybara (*Hydrochœrus capybara*), is simply

an exaggerated Cavy specialized for an aquatic life, as testified by its webbed feet. It inhabits the great rivers of South America, and is not unlike a small pig in general appearance and

Fig 95 —The Unau or Two toed Sloth (*Cholœpus didactylus*)

size. The writer well remembers seeing a tame specimen, which had escaped from the grounds of its owner and swum down the Teign estuary to Teignmouth, being exhibited in the lifeboat-house there as "a pigfacious hippopotamus".

Order 12.—Edentates (Edentata)

This very remarkable group includes a number of both Old and New World forms, which are rather low in the scale, and have had to adopt various expedients in order to avoid being exterminated by the active competition of more highly organized forms. It is very doubtful whether the Old World forms have any special relation to the New World ones, or in other words the order is a very artificial one. This comes out strikingly when an attempt is made to discover common characters. About all that can be said is, that the teeth are highly peculiar in character, and that the digits are provided with curiously modified curved hoofs. As to the former structures the term "edentate", *i.e.* toothless, is somewhat misleading, for though this is the case with some forms, it is not generally true, though the front teeth are always more or less deficient. A further point is that the teeth are always devoid of enamel.

Most of the Edentates are found only in South America, and of these the following are representative species:--The Two-toed Sloth (*Cholœpus didactylus*) (fig. 95) of Guiana and Surinam; the Six-banded Armadillo (*Dasypus sexcinctus*) (fig. 96) of the South American pampas; and the Ant-Bear (*Myrmecophaga jubata*) of Paraguay. Old World forms are: The Cape Ant-Eater or Aard-Vark (*Orycteropus Capensis*) (fig. 97) of South Africa, and the Long-tailed Pangolin (*Manis pentadactyla*) (fig. 98) of West Africa.

Order 13.—Pouched Mammals (Marsupialia)

This is the only order in the Mammalian sub-class Metatheria, under which heading its leading characters have already been given (p. 68).

The great bulk of existing Marsupials are confined to Australia and its adjacent islands, as far as Celebes, though the order is also represented in America. The great interest attached to the Australian forms is found in the way they have become specialized in various directions to fill the most varying places in the economy of nature. Other more highly organized mammals having been absent, they have had the field to themselves without other serious competition, and the places occupied in most parts of the world

POUCHED MAMMALS (*Marsupialia*)

1 Tree Kangaroo of New Guinea (*Dendrolagus ursinus*).
2 Koala (*Phascolarctos cinereus*)
3 Water Opossum (*Chironectes minima*)
4 Pig footed Bandicoot (*Chæropus castanotis*)
5 Tasmanian Devil (*Sarcophilus ursinus*)
6 Squirrel like Flying Phalanger (*Petaurus sciureus*)
7 Jerboa Pouched mouse (*Antechinomys laniger*)
8 Philander Opossum (*Didelphys philander*)
9 Great Grey Kangaroo (*Macropus giganteus*)
10 Tasmanian Wolf (*Thylacinus cynocephalus*)
11 Hairy-nosed Wombat (*Phascolomys latifrons*)
12 Gunn's Bandicoot (*Perameles Gunni*)
13 Common Dasyure (*Dasyurus viverrinus*).

Numbers 3 and 8 are American forms the remainder belong to the Australian region

GROUP OF POUCHED MAMMALS (MARSUPIALIA)

Fig. 96 The Six banded Armadillo or Poyou (Dasypus sexcinctus)

by such groups as Carnivora, Insectivora, &c., are here filled by marsupial sub orders.

The American marsupials have had to compete with forms

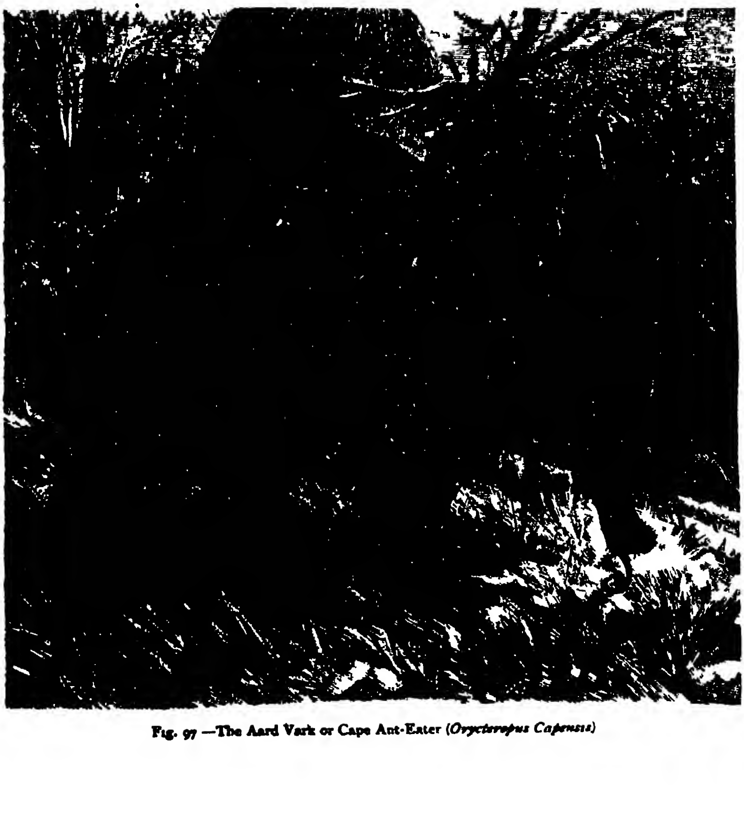


Fig. 97.—The Aard Vark or Cape Ant-Eater (Orycteropus Capensis)

better adapted to struggle for existence, and play but a subordinate part in the fauna of that continent. They consist of the Opossums, found both in North and South America, and of a small creature Cœnolestes recently discovered in the latter continent. The Common Opossum (*Didelphys Virginiana*) has

Fig. 98.—The Long tailed Pangolin (*Manis pentadactyla*)

a wide distribution in North America, from Canada to Mexico. It is the well-known "'possum" of American story and verse.

Order 14.—Egg-laying Mammals (Monotremata)

Like the preceding one, this order is the only one in its subclass (Prototheria), of which the leading characters have already been given (p. 69). It will suffice to remark here that its members are only found in the Australian region, like the majority of Marsupials, and having had to compete with these comparatively more powerful forms, have been prevented from occupying more than a subordinate position in the fauna of that region.

CHAPTER III

STRUCTURE AND CLASSIFICATION OF BIRDS

Though Birds are familiar objects to all, and obviously characterized by the possession of wings and feathers, these are not the only essential features distinguishing them, and it will clear the ground to briefly describe some well-known and typical example of the class. This is the better worth doing since the great bulk of existing birds resemble one another to a much greater extent than is the case with mammals.

As convenient a type as any, and one possessing special interest from the fact that Darwin devoted a very large amount of attention to it from the evolutionary stand-point, is the Pigeon (*Columba livia*). Of this there are a large number of domestic varieties, some very peculiar in appearance, but for our purpose the best is the one known to fanciers as the "Blue Rock", which best represents the central form from which the different varieties have sprung, and which is found wild in Europe, North Africa, and West Asia as far as India.

The wild Blue Rock nests in caves or clefts of the rock, and is of common occurrence round the northern coasts of Ireland and Scotland. Its prevailing hue is grey, but the rump is white, and the neck and upper part of the breast green and purple, with a metallic sheen. There is a characteristic broad black bar running across the end of the tail, while the wing is crossed by two similar but narrower bands.

External Characters (fig. 99).—The outlines of a bird are mainly determined by the feathers, as is strikingly seen on comparing a living bird with a plucked specimen, the latter presenting a very comical appearance. The head is well rounded behind, in correspondence with the presence of a large brain, while the face is produced in front into a somewhat conical horny beak, at the base of which are situated the two slit-like nostrils, over

hung by a bare patch of swollen skin, the *cere*. The large eyes are provided not only with upper and lower eyelids, but also with a translucent *nictitating* membrane, or third eyelid, which can be rapidly twitched over the front of the eye by special muscles A narrow bare area of skin surrounds each eye, and in such breeds as the Carrier, this area and the cere are highly developed into peculiar fleshy outgrowths. Below and behind the eye is the

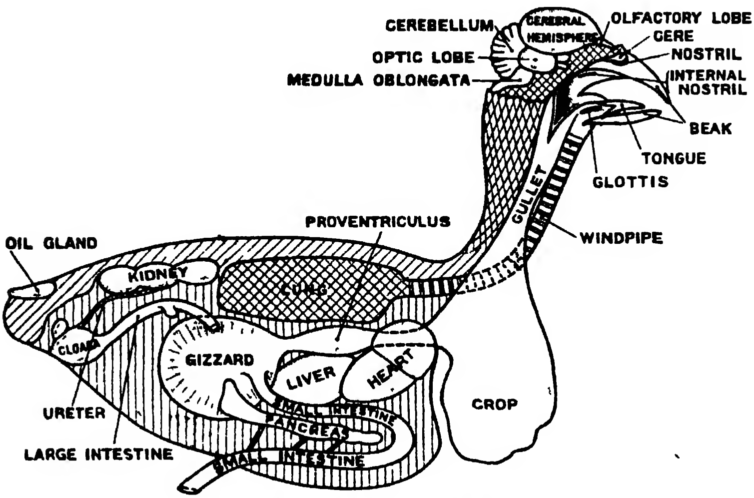


Fig 99 —General Structure of Pigeon

small round auditory aperture, which is not provided with a pinna as in most mammals.

The long and exceedingly mobile neck is sharply marked off from the stout boat-shaped trunk, which is terminated by a stumpy tail, on the upper surface of which is a prominent papilla carrying the aperture of the large oil-gland. On the under side of the trunk, near its hinder end, is the opening of the cloaca, a small chamber into which open the intestine, the kidney-ducts, and the ducts of the reproductive organs.

The body of a bird exhibits innumerable adaptations to an aerial life, and this is seen very strikingly in the fore-limbs, which are modified into wings, quite different, however, in structure from those of a bat (see p. 81). The same sections are present as in a mammal, *i.e.* upper arm, fore-arm, and hand, but there are considerable differences in detail. In so far as folds of skin

connect upper arm and fore-arm in front, and upper arm and trunk behind, there is a certain resemblance to the bat's wing, but we do not find in the bird long slender fingers supporting a well-developed membrane, but a reduced hand possessing only three modified digits. The efficient part of the wing consists of feathers, and the limb is specialized so as to serve as a firm support for these.

When a bird is not flying it is supported by the hind-limbs, but the problem of bipedal progression is not solved here in the same way as in a human being (see p. 66), where the trunk is raised into a vertical position and brought into the same line as the legs. The hind-limbs of a bird are, as it were, shifted forwards so that the body is balanced somewhat obliquely between them. There are, however, some forms, such as Penguins (fig. 127), in which the trunk is raised into an approximately upright position, but even then the resemblance to the attitude of an erect human being is remote, for not only is the thigh attached as in other birds, but it points slantingly upwards instead of being directed downwards. It would not indeed be possible for a bird to completely straighten out its leg, for the thigh is more or less enclosed in the boundaries of the trunk, and is not entirely free, as in ourselves.

It is also noticeable that the regions of a bird's leg, with the exception of the uppermost one, or thigh, do not exactly correspond with the subdivisions found in a mammal. The other two sections may be called, for convenience, lower leg and foot, but the ankle-joint between them is not in exactly the same position as in the last-named group. This will be more fully explained in dealing with the endoskeleton. The digits are four in number, instead of five as in a typical mammal, the digit corresponding to the little toe of which being absent. The great toe is turned backwards, and, since the body is supported upon the digits while the metatarsus and tarsus are raised from the ground, the bird may be termed digitigrade.

Skin and Exoskeleton.—The thin skin is made up, as in a mammal, of epidermis and dermis, and the former gives rise to a well-marked exoskeleton, consisting of beak, claws, scales, and feathers. The ***beak*** comes under this heading in so far as the horny sheaths which cover both upper and lower jaws are concerned, while the toes are provided with ***claws***, and the feet are

covered by overlapping *scales.* The characteristic parts of the skeleton, however, are the *feathers* (fig. 100), structures which are possessed by all birds, but by no other animals. They do not cover the entire surface of the body, but are limited to certain feather tracts (*pterylæ*), between which are bare patches (*apteria*). Feathers, like hairs, spring from pits in the skin, and are renewed from time to time, during a moulting season. They are of three kinds: 1. small downy *filoplumes*, consisting of a stalk with a tuft

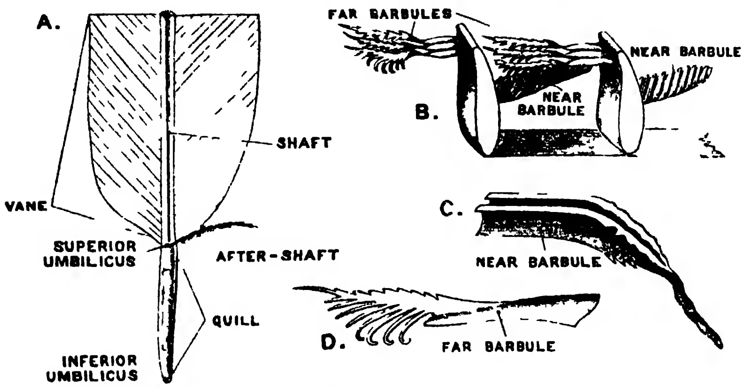


Fig. 100.—Structure of a Feather (there is no after-shaft in the Pigeon)

A, Base of quill feather. B, barbs and barbules (much enlarged). C and D, separate barbules still further enlarged.

of filaments at the end; 2. *contour* feathers, which cover most of the body, and, as the name indicates, determine its shape; and 3. large *quill-feathers* used in flight, and attached to the wings and tail. The last two kinds closely resemble one another in structure, and it may suffice to describe one of the quills, which are the most specialized and characteristic of feathers. Both light and strong, with a large surface for opposing to the air, they are exquisitely adapted to their purpose, even in the minutest details of their structure. We can distinguish between a central shaft, consisting of a hollow *quill* continued into a solid *rachis*, and oblique filaments or *barbs* projecting from each side of the rachis and constituting with it the *vane.* Each barb is provided with an oblique set of *barbules* on its far or distal side, facing the end of the feather, and a similar set on its near or proximal side, facing towards the base of the feather. The barbules of the distal row are provided with hooklets, which catch on to ridges possessed by the row of proximal barbules immediately in front of them.

Twenty-three quills (remiges) are attached to the hinder margin of each wing, eleven of them being *primaries* fixed to the hand, while the twelve others are *secondaries* borne by the fore-arm. The bases of these quills are covered above and below by other feathers known respectively as upper and lower *wing-coverts.* There is also a tuft of feathers, the *bastard wing* (ala spuria), upon the thumb.

Twelve *tail-quills* (rectrices) are attached in the form of a fan to the stumpy tail, and the bases of these are covered by upper and lower *tail-coverts.*

The *contour feathers,* including the coverts and the bastard wing, resemble quill-feathers on a small scale, but when they are plucked away a number of *filoplumes* are found among them, each consisting of a stalk bearing a loose tuft of barbules at its end. The *down-feathers* with which the nestling is covered closely resemble these.

Endoskeleton (fig. 101).—The same regions and parts can be recognized as in a mammal, but there are very considerable differences in detail, most, if not all, of which are related to the mode of life. The bones are particularly light and spongy, while many of them contain air instead of marrow, one of the arrangements whereby the specific gravity of the body is reduced as an adaptation to flight.

A number of features distinguish the *skull* from that of a mammal, one being that in the adult the bones are fused together so as to obliterate the junctions between them. This feature, however, is also seen in the lowest mammals, *i.e.* the Spiny Ant-Eater and Duck-billed Platypus, and is not the only point in which these creatures show a resemblance to birds. We have seen that at the back of a mammal's skull (p. 28) there are two rounded occipital condyles which fit into corresponding cups in the first joint of the backbone, but in the pigeon only one such condyle is to be seen, and as a result of this the head can be turned very freely about from side to side. There is also a remarkable peculiarity in the attachment of the lower jaw to the skull, as this takes place by the intervention of a special bone, the *quadrate,* there being thus a double jaw joint, permitting the mouth to be opened very widely, a capacity which must have struck anyone who has ever examined a nest of young pigeons, sparrows, or canaries. It may also be noted in a young skull that each half

of the lower jaw is made up of several pieces instead of only one as in a mammal.

The *backbone* is very long and there are remarkable contrasts between its several regions, for whereas the neck vertebræ are united together by saddle-shaped surfaces so as to give extraordinary flexibility, the vertebræ of the trunk are largely fused

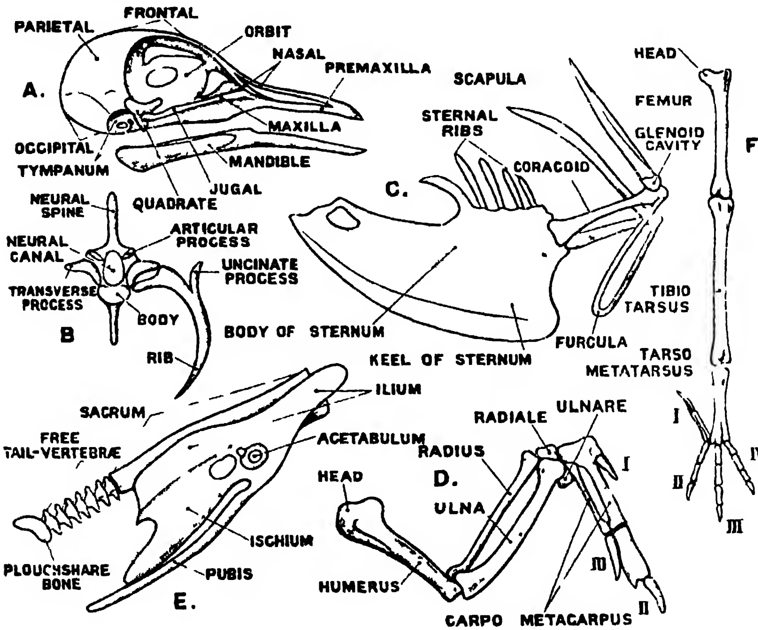


Fig. 101. Skeleton of Pigeon

A, Skull; B, vertebra and rib, front view; C, sternum and shoulder girdles; D, wing; [illegible] leg

together so as to confer great rigidity, an important matter in connection with the requirements of flight. What is called the "sacrum" in a pigeon is made up by the union of vertebræ belonging to very different regions, including one thoracic, six lumbar, two sacral proper, and five caudal. The remaining vertebræ of the abbreviated tail are ten in number, and the last four of them are fused into a laterally-flattened *ploughshare bone*, which supports the tail-quills.

Since the walls of the thorax are fairly mobile in a bird, and by their movement help in breathing, the breastbone and ribs are hinged on to the backbone so as to permit of this.

All the five thoracic vertebræ bear *ribs* which unite with the breastbone, and each rib in its upper section possesses a backward projection, the *uncinate process*, absent in all mammals. It should also be noted that the posterior neck vertebræ bear small free ribs.

The *breastbone* or sternum of a pigeon is exceedingly large, and is in particular distinguished by the presence of a very prominent vertical plate or keel on its under side. The use of this is to give a large surface to which the powerful muscles of flight are attached. A bat's sternum possesses a small keel for a similar reason.

Skeleton of Fore Limb. The special function of this being to serve as a firm support for the wing quills, it is not surprising to find that the bones of the hand have undergone a good deal of reduction in number, and also of fusion, the digits being only three, corresponding to the thumb and first two fingers of a mammal. Such a hand skeleton as that described for Man (p. 31), made up of numerous small bones flexibly united together, is very suitable for a limb capable of performing all sorts of complicated movements, but much too elaborate for a mere support, as in the case of a wing.

The upper part of the limb skeleton, or *shoulder-girdle*, includes three bones: the dorsal narrow *scapula*, the rod-shaped ventral *coracoid* which unites with the sternum, and a collar bone or *clavicle*. In the possession of a distinct coracoid, Birds and Monotreme Mammals agree (p. 138). The two narrow curved clavicles are firmly fused together into the familiar 'merry thought' or *furcula*, which acts as a spring and keeps the two wings well separated.

Skeleton of Hind Limb. The *hip girdle* is made up of the same three elements as in a mammal, *i.e.* *ilium*, *ischium*, and *pubis*. The ilium is very large and runs both fore and aft, uniting by its inner surface with the long "sacrum", thus affording a very firm support to the body when the bird rests or walks. Both ischium and pubis, especially the latter, are narrow and backwardly-directed, and do not unite with one another in the mid-ventral line as in a mammal (see p. 31).

The chief peculiarity in the bones of the free part of the leg is found in the ankle, for the *tarsus*, instead of being made up of a number of small irregular bones, as in

the mammal (see p. 32), consists, in the very young bird, of two elements only, of which one fuses with the tibia to form a tibio-tarsus, while the other fuses with three of the metatarsals, these also uniting with one another, the compound product being known as the "tarso-metatarsus". It will thus be seen that what corresponds to the ankle-joint of the human foot (p. 32) comes in the middle of the tarsus, and not between it and the bones of the lower leg. The great toe possesses a metatarsal which is distinct from the others, and this digit therefore has a greater power of movement. The remaining point deserving mention here is in regard to the number of phalanges in the various toes. It will be remembered that in Man (p. 31), and the same thing is true for mammals generally, the great toe has two and the remaining toes three phalanges each. A bird has similarly two phalanges in the great toe and three phalanges in the second toe, but the third toe possesses four, and the fourth five, thus giving the regular succession two, three, four, five, each digit possessing one more phalanx than its number in the series.

Digestive Organs (fig. 99).—The pigeon, like all existing birds, is entirely devoid of teeth, and its beak is only useful for picking up food, not being capable of breaking up the hard grain on which the animal largely feeds. A temporary receptacle for food is therefore necessary, and this is found in the large *crop* into which the gullet swells. A further peculiarity, common to all birds, is found in the nature of the stomach, which consists of two parts, chemical stomach (proventriculus) and gizzard. The former looks like a swelling at the end of the gullet, but is distinguished by the presence of numerous *gastric* or *peptic glands* (see p. 37) imbedded in its mucous membrane, and secreting gastric juice. The *gizzard* is a rounded and somewhat flattened structure with a tough lining and exceedingly thick muscular walls. As is well known, it serves to grind up the food, its action being assisted by small stones and other hard bodies which are swallowed for the purpose. The stomach is followed by a long *small intestine* into which the *liver* and *pancreas* pour their secretions; and a much shorter *large intestine*, opening into a *cloaca*, which communicates with the exterior by a cloacal aperture.

Circulatory Organs (fig. 102).—As in a mammal, both blood

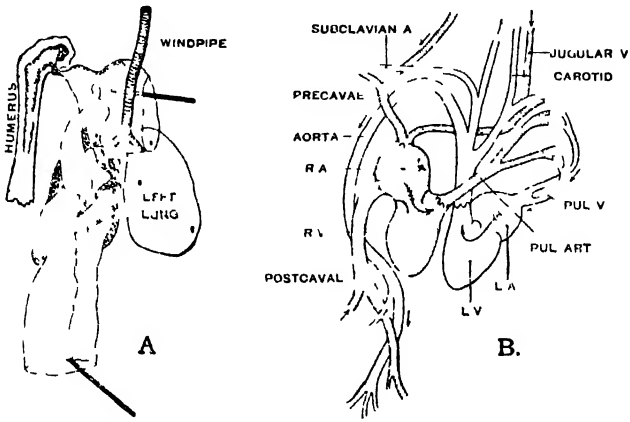
and lymph systems are present, but we need only consider a few points concerning the former.

The blood is much hotter than that of a mammal, maintaining a temperature of about 103° F. on the average as against 98° F., a fact which has relation to the extreme activity of birds, and the intensity, so to speak, of all their life processes. The well-developed investment of feathers by which the body is covered, and which entangles a large amount of air, is of great importance as a non-conducting coat, which prevents the too rapid dissipation of the heat of the body without checking ventilation of the body surface. A drop of pigeon's blood examined under the microscope shows the same constituents as are seen in a mammal (see p. 39), *i.e.* a liquid *plasma* in which are suspended *white* and *red corpuscles.* The latter, however, though discs, are of a pointed oval shape instead of being circular, and each of them encloses a firmer particle or nucleus.

The pigeon's *heart* and *blood-vessels* agree in essential respects with those of a mammal (see p. 39), but there are numerous differences in detail. Thus, though the heart is four-chambered and the impure blood of the right side is thus completely separated from the pure blood of the left side, there are differences as regards the valves, especially the one between right auricle and ventricle, which is a muscular flap instead of consisting of three membranous pieces. The great artery of the body, the *aorta*, where it arises from the heart, curves round to the right and not to the left. The enormously large muscles of flight, which make up the flesh of the breast, are provided with large blood-vessels.

Breathing Organs and *Organs of Voice* (fig. 102).—The separation between food-tract and breathing-tract is less complete here than in a mammal (see p. 34), for the hinder openings of the nasal cavities (*posterior nares*) are situated on the roof of the mouth instead of farther back. Upon the floor of the pharynx the slit-like glottis is situated, but this is not guarded in front by an epiglottis It leads into the larynx, which is *not* in birds the organ of voice, and is continued into the very long windpipe (trachea) that divides into two branches (*bronchi*) for the lungs. These air-passages are not supported by hoops of cartilage, as in mammals (p. 46), but by bony rings. From this point onwards a number of striking peculiarities are

encountered, for the lungs do not constitute the only goal of the in-breathed air, but communicate with a number of thin-walled *air-sacs*, and these again with the air-filled cavities in the bones. The only other animals which are so thoroughly permeated by air are insects, and in them, as in birds, one end to be gained is the reduction of the specific gravity of the body as an aid to flight. The small *lungs*, though spongy, are not freely movable in the thoracic cavity, but are firmly fixed to its roof



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and there being no midriff as in a mammal (see p. 46), there is no sharp boundary between thoracic and abdominal regions. The bronchi branch out in their respective lungs, and their larger branches run to the lung surface, where they open into the large thin-walled air-sacs, which are placed in various positions. Some of the anterior air-sacs communicate with the air-spaces contained in certain bones, as, *e.g.*, the humerus and sternum. The mechanical part of breathing is brought about by the movement of the ribs and sternum, much as in a mammal (p. 46), but here there is, of course, no diaphragmatic breathing. The entering air rushes into all the air-sacs, and the work to be done by diffusion is not so great as in a mammal. The reason for this is, to keep the process of blood oxygenation

going very rapidly, as, if this were not the case, the high temperature of the body could not be maintained.

Voice.—Although the pigeon possesses a larynx, this is not the organ of voice, which consists of a structure known as the ***song-box*** or ***syrinx***, formed by the modification of the extreme end of the windpipe and the beginning of the two bronchi to form a small resonant chamber (*tympanum*) into which an elastic fold projects. The sound is produced by vibration of this fold, and it can be stretched to various extents so as to alter the pitch of the note.

Organs of Movement.—As in the human subject, the *white corpuscles* of blood and lymph are able to creep about by means of amœboid movement (p. 39), and the windpipe and certain other structures are lined by *ciliated membranes* (p. 49); but, as before, the chief movements of the body are brought about by *muscular action.* The most interesting peculiarities in the muscular system are connected with flight and with perching. The large fleshy mass covering the breast is made up of the pectoral muscles, which are attached to the wings in such a manner as to pull them alternately up and down; but this is not the place to furnish details, which will be given farther on in connection with locomotion.

The *perching mechanism* is an arrangement by which the toes can be all brought together at the same time by a pull exerted upon a single tendon connected with two muscles of the leg. When a bird is roosting, the weight of the body bends the limb in such a way as to pull on this tendon and bring all the toes firmly against the branch or other supporting object, the danger of falling off during sleep being thus averted.

Nervous System (fig. 103).—The *brain* of the pigeon is extremely short and broad, and is distinguished by several peculiarities. The cerebral hemispheres are large and rounded, but are quite smooth externally, and are not, as in mammals, united across the middle line by a fibrous band or corpus callosum (see p. 52). Both these points are related to the comparatively small intelligence of the animal. The organs of smell are not well developed, and therefore, as might be expected, the olfactory lobes are of small size; but on the other hand, in accordance with the unusually acute vision, the optic nerves, optic tracts, and optic lobes are very large.

These last are two rounded elevations situated one on each side, while the corresponding parts in a mammal are four in number, and have a dorsal situation. The cerebellum is very large, and marked by deep transverse furrows.

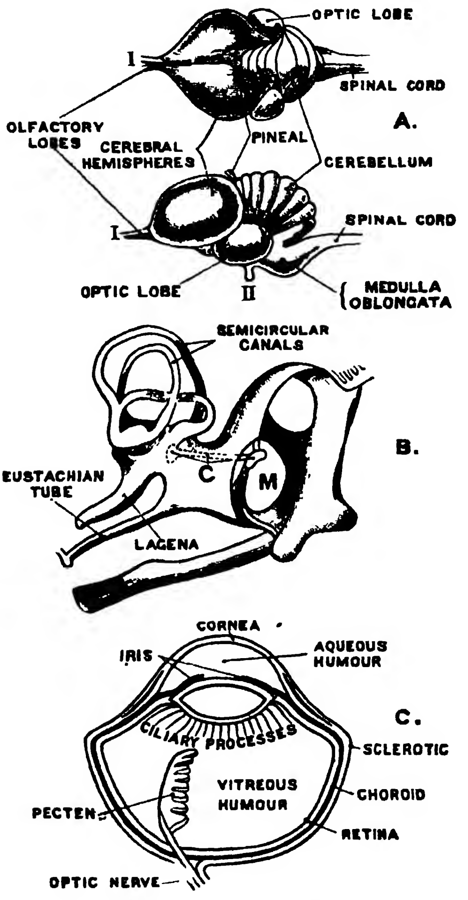


Fig 103.—Structure of Pigeon

A, Brain from above and from left side: I, olfactory nerve, II, optic nerve B, Organs of hearing (much enlarged); C, columella M, position of tympanic membrane, C, Diagrammatic section of eye (enlarged).

Sense Organs (fig. 103).—Only the ear and eye deserve special mention under this heading. The *organs of hearing* consist, as in a mammal (see p. 56), of internal, middle, and external ears, but there are a number of differences in detail. The internal ear or membranous labyrinth differs most as regards the *cochlea*, which is a slightly-curved tube (lagena) instead of being spirally coiled. In the middle ear it may be noted that instead of a chain of auditory ossicles there is a minute rod, the *columella*, which runs across the tympanic cavity from its external membrane to the *fenestra ovalis*. The external ear consists simply of a passage leading down from the outside of the head to the tympanic membrane, there being no external flap or pinna. It will be remembered, however, that the pinna is also absent in certain aquatic mammals, such as the whales and the true seal.

The *eye* of a bird is not, as in a mammal, approximately spherical, but consists of outer and inner halves possessing very

different degrees of curvature, the former almost resembling a cone with its apex rounded off instead of being pointed. Within the outer part of the sclerotic, or firm white external eye-coating, there is a circlet of small overlapping bony plates. The remaining most striking difference is seen in the presence of a *pecten*, a folded structure which projects into the vitreous humour close to the point where the optic nerve pierces the eyeball to branch up in the retina or sensitive innermost eye-coating.

It was noticed under external characters that there is a third eyelid in addition to the usual upper and lower ones. Some mammals, as the rabbit, possess such an eyelid, though it is not so mobile.

Development (fig. 104)—All birds lay eggs, protected externally by a firm limy *shell*, and the lowest mammals agree with them

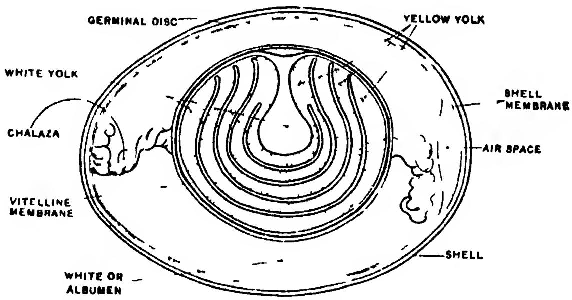


Fig 104—Structure of Hen's Egg

in this respect. One or both parents in turn sit upon or incubate the eggs, thus providing the necessary warmth without which the young bird cannot develop. Most of the egg consists of material which will serve for the nourishment of the embryo, the body of which is evolved from a very small patch (*germinal disc*), to be seen on one side of the yellow part known as the *yolk*. The part of the yolk on which the germinal disc rests is lighter than the rest, and this side therefore floats upwards in the glairy matter termed the "white", or more properly speaking the *albumen*. Hence the embryonic part of the egg is kept constantly turned towards the source of heat, *i.e.* the incubating parent. Young pigeons are hatched in a very imperfect state, and have to be fed for some time by the parents, part of their food consisting of a whitish material, the so-called "pigeon's milk", secreted by the

lining of the crop. The helpless nestling is very imperfectly clad with feathers, and these down-feathers are much simpler in nature than the ordinary feathers of the adult bird.

CLASSIFICATION OF BIRDS

Excluding fossil forms, birds are divided into two sub-classes of very unequal size: I. Flying Birds (Carinatæ), of which the Pigeon is an example; and II. Running Birds (Ratitæ), of which the best-known kind is the Ostrich.

I. Flying Birds (Carinatæ) are more or less perfectly adapted for flight, as will have been seen from the typical example just described. The most striking characters are found in the structure of the wings and the keeled sternum, in reference to which latter feature the group is technically called Carinatæ (L. *carina*, a keel).

Although the existing species of flying birds are extremely numerous, they agree so closely among one another in most essential features that it is exceedingly difficult to divide them into orders, but eighteen of these are commonly recognized, though the distinctive characters of many of them are founded upon comparatively trivial matters, and we do not get the broad lines of division existing in the case of Mammals. The orders are as follows:—

1. Perching Birds (Passeres); 2. Picarian Birds (Picariæ); 3. Owls (Striges); 4. Parrots (Psittaci); 5. Pigeons and Sand-Grouse (Columbæ); 6. Gulls (Gaviæ); 7. Plovers (Limicolæ); 8. Bustards and Cranes (Alectorides); 9. Rails (Grallæ); 10. Game-Birds (Gallinæ); 11. Tinamous (Crypturi); 12. Eagles and Vultures (Accipitres); 13. Ducks, Geese, and Flamingoes (Anseres); 14. Herons and Storks (Herodiones); 15. Pelicans and Cormorants (Steganopodes); 16. Petrels and Albatrosses (Tubinares); 17. Divers and Grebes (Pygopodes); 18. Penguins (Impennes).

Order 1.—Perching Birds (Passeres).

This order is regarded as the highest of the sub-divisions of birds, and the large majority of them are included in it, more particularly those which are familiarly known as "song-birds". The first toe can be moved independently of the others, which is not the case in other birds, and possesses a larger claw than

they do. In most cases the back of the metatarsus is protected by two narrow elongated plates, instead of by scales. There are generally ten, or it may be nine, primary quills in the wing, which is covered by only a few small contour feathers. The tail-quills are usually twelve in number. The young are helpless and almost destitute of feathers.

Among the enormous number of birds included in this order are the following representatives of important families:—1. Crows; 2. Birds of Paradise; 3. Bower-Birds; 4. Starlings; 5. Orioles;

Fig. 105.—Rook (*Corvus frugilegus*)

6. Finches; 7. Weaver-Birds; 8. Buntings; 9. Larks; 10. Wagtails; 11. Creepers; 12. Nuthatches; 13. Sun-Birds; 14. Tits; 15. Shrikes; 16. Thrushes and Warblers; 17. Wrens; 18. Swallows; and 19. Lyre-Birds. The British species belonging to these families, if any, will be enumerated, except in the case of rare stragglers.

1. *Crows* and their allies are large birds with strong beaks, and nostrils protected by bristles. Many of them are black or black and white, and they are practically cosmopolitan, being absent, however, from New Zealand, Among British forms the Raven (*Corvus corax*) is entirely black, as are the Carrion Crow (*Corvus corone*) and the Rook (*Corvus frugilegus*) (fig. 105), there being, however, in the latter a bare patch extending round the base of the beak. The Jackdaw (*Corvus monedula*) has a grey neck, while the long-tailed Magpie (*Pica rustica*) is black and white, as the name indicates. The Jay (*Garrulus glandarius*) is a much more brightly-coloured member of the same family, its

plumage exhibiting white, black, brown, and blue, while there is a handsome crest upon the head.

The remaining British species are: Hooded Crow (*Corvus cornix*), Nutcracker (*Nucifraga caryocatactes*), Chough (*Pyrrhocorax graculus*).

Fig. 106.—Great Paradise Bird (*Paradisea apoda*)

2. The *Birds of Paradise* are closely related to the crows in structure, but are remarkable for the gorgeous and varied plumage of the males, certain of the feathers being prolonged and modified in various ways. The region from which such feathers spring differs in different species. Birds of Paradise are for the most

part limited to New Guinea and the neighbouring islands, though they also range into the north of Australia. The Great Paradise Bird (*Paradisea apoda*) of the Aru Islands is depicted in fig. 106

3. *Bower-Birds* constitute a small family mainly confined to Australia, though also found in New Guinea, and are chiefly interesting because they construct and decorate so-called "bowers", which appear to be solely used for the purpose of amusement. A well-known form is the Satin Bower-Bird of New South Wales (*Ptilonorhynchus holosericeus*).

Fig. 107 Starlings

Common Starling (*Sturnus vulgaris*)

4 *Starlings* (fig 107) constitute a well-known family with a wide distribution in the Eastern hemisphere, being absent only from Australia. They do not, however, occur in America. The beak is fairly long and often slightly curved, while its base is free from bristles Flocks of these birds can often be seen in meadows hunting for insects and worms. Another characteristic feature is that of the ten primary wing-quills; the first is less than half the length of the second

The Common Starling (*Sturnus vulgaris*), immortalized in Sterne's *Sentimental Journey*, is a refreshing exception to the general rule for British birds, its numbers being on the increase. The black plumage, shot with green and blue, and tipped with buff, is extremely handsome. There is one other British species, the Rose-coloured Starling (*Pastor roseus*).

5. *Orioles* or Golden Thrushes are characteristic of Africa and South Asia, though they are represented in Australia and Europe. The beak is slender and almost straight, the legs short, and the plumage brilliant.

The Golden Oriole (*Oriolus galbula*) of continental Europe

and South-west Asia is known as a visitor in this country. In colour it is golden-yellow, with black on the wings and tail, and the call-notes of the male are flute-like in tone.

6. *Finches* make up a very large family, absent only from the Australian region, and characterized by strong conical beaks adapted for feeding upon seeds and grain, while there are only nine primary wing-quills instead of ten. The food is by no means limited to seeds and the like.

The following small British birds belong here:—Sparrow (*Passer domesticus*); Tree-Sparrow (*P. montanus*); Bullfinch (*Pyrrhula Europæa*); Chaffinch (*Fringilla cœlebs*); Brambling (*F. montifringillina*); Linnet (*F. cannabina*); Mealy Redpole (*Cannabina linaria*); Lesser Redpole (*C. rufes*); Twite (*C. flavirostris*); Greenfinch (*Ligurinus chloris*); Goldfinch (*Carduelis elegans*); Hawfinch (*Coccothraustes vulgaris*); Siskin (*Chrysomitus spinus*); Crossbill (*Loxia curvirostra*).

7. *Weaver-Birds*, remarkable for the way in which they intertwine fibres to form their nests, resemble finches in appearance and in their stout conical beaks, but possess ten instead of nine primary wing-quills as in the latter. The family is more particularly characteristic of Africa south of the Sahara, but is also well represented in South Asia and in Australia. The Java Sparrow or Rice-Bird (*Munia oryzivora*) is familiar in this country as a cage-bird.

8. *Buntings* are finch-like forms inhabiting the colder parts of the Old World. They differ from the true finches in minor features, one of which is that when the beak is shut its edges do not come into contact except at the base and tip.

There are several British species, of which the most familiar is the Yellow Bunting (*Emberiza citrinella*), better known as the Yellow Hammer.

The remaining British species are:—Cirl Bunting (*Emberiza cirlus*); Corn Bunting (*E. miliaria*); Reed Bunting (*E. schœniclus*); Snow Bunting (*Plectrophenax nivalis*).

9. *Larks* constitute a tolerably large group, limited with but few exceptions to Europe, Asia, and Africa, where they are most abundant in plains and deserts. Their powers of song are known to everyone. The first toe is provided with a very long straight claw.

The Skylark (*Alauda arvensis*) and Woodlark (*A. arborea*) are well known in Britain. The Shore Lark (*Otocorys alpestris*) is a visitor.

BRITISH PERCHING BIRDS (*Passeres*)

The species figured are Finches (1, 2, 5), a Bunting (4), and a Tit (3). Finches (*Fringillidæ*) live in wooded districts, and their short stout conical beaks are adapted to seed-eating. Buntings (*Emberizidæ*) inhabit open grassy localities, and are easily distinguished from Finches by a notch in the side of the beak. Tits (*Paridæ*) are chiefly found among trees, and feed for the most part on insects.

1. Bullfinch (*Pyrrhula Europæa*)
2. Chaffinch (*Fringilla cœlebs*)
3. Blue Tit (*Parus cœruleus*)
4. Yellow-hammer (*Emberiza citrinella*).
5. Goldfinch (*Carduelis elegans*).

BRITISH PERCHING BIRDS (PASSERES)

1. Bullfinch.
2. Chaffinch.
3. Blue-Tit.
4. Yellow-Hammer.
5. Goldfinch.

10. *Wagtails*, with their allies the *Pipits*, make up a small family which, though found in all parts of the world, except the Pacific Islands, is especially characteristic of the northern parts of Europe and Asia. The body is slender and the tail long. The narrow-pointed beak is well suited for the capture of insects, and the feet are somewhat like those of larks, except that the claw of the first toe is more curved. Most of the birds here included are found chiefly on the ground, and run very quickly.

Common British species are the following:—Pied Wagtail (*Motacilla lugubris*); Meadow Pipit or Titlark (*Anthus pratensis*).

The other native species are the following:—White Wagtail (*Motacilla alba*); Blue headed Wagtail (*M. flava*); Grey Wagtail (*M. melanope*); Yellow Wagtail (*M. Raii*); Rock Pipit (*Anthus obscurus*); Richard's Pipit (*A. Richardi*); Tree Pipit (*A. trivialis*).

11. *Creepers* are a small family of wide distribution, with long curved beak and sharp claws. They are adapted for the pursuit of insects upon the trunks of trees, walls, and similar places.

The only resident British species is the Tree Creeper (*Certhia familiaris*), which has a wide range in the Northern hemisphere. Though fairly common, its plumage harmonizes so well with the surroundings that it often escapes observation. The tail is stiffened, and its pointed quills are of great assistance in climbing.

12. *Nuthatches* constitute another small family of climbing birds, somewhat more widely distributed than the Creepers, being absent only from South America, Africa south of the Sahara, and the Pacific Islands. They differ in no very important respect from the Creepers. Their food consists not merely of insects, but also of nuts.

Our only native species is the Nuthatch (*Sitta cæsia*), common in the wooded parts of Central and South Europe, and also found in North Africa. It also ranges into South-west Asia, but, unlike the Creeper, is unknown in North America.

13. The *Sun-Birds* are small, brilliantly-coloured forms ranging through the tropics of the Old World, and often confounded with the humming-birds, which they resemble in appearance and habits, though there is no close relationship between the two groups.

14. *Tits* or *Titmice* are small active birds, the general appearance of which is well known to everyone, and which, though

specially characteristic of the northern hemisphere, are found in most parts of the world. The beak is short and conical, and the first wing-quill is never more than half the length of the second one. These birds inhabit trees, and chiefly feed on insects, though vegetable food is by no means disdained. A meat-bone or partly-opened cocoa-nut placed outside the window of a house is almost certain to attract any tits which may be in the neighbourhood.

The best-known British species is the Blue Titmouse (*Parus cæruleus*), which possesses extremely beautiful plumage, exhibiting shades of blue, yellow, yellowish-green, and white. It ranges throughout most of Europe, and is abundant in Asia Minor.

Other typical native forms are:—Coal-Tit (*Parus ater*); Crested Tit (*P. cristatus*); Great Tit (*P. major*); Marsh Tit (*P. palustris*); Long-tailed Tit (*Acredula caudata*).

15. *Shrikes* make up a fairly large family of tree-inhabiting birds which have their head-quarters in Africa, though they are found in all parts of the world, except South America and New Zealand. Their food consists of insects, and also in some cases of small vertebrates, and in accordance with this the beak is strong and often somewhat hooked.

The most abundant British species is the Red-backed Shrike (*Lanius collurio*), the plumage of which is mainly chestnut above and buff on the under side. Like other "butcher-birds", as these forms are often called, this form has the habit of impaling its victims upon sharp thorns. Its range includes most of Europe, South-west and Central Asia, and in winter it is found as far south as the Cape. Another native form is the great Grey Shrike (*L. excubitor*).

16. *Thrushes* and *Warblers* together constitute an enormous group of cosmopolitan birds distinguished for their powers of song. The beak is slender and bent a little at the end, and the first wing-quill is very short. Some feed entirely on insects, but others eat berries and the like as well. The plumage is quiet in colour, and there is not much difference in this respect between the sexes.

Thrushes are stoutly-built omnivorous birds, in which the young differ from the adults in their spotted plumage. They are commonest in South America, but are found in all parts of the world, except Madagascar and New Zealand.

Fig 108 —Warblers

1 Barred Warbler (*Sylvia nisoria*) 2 Lesser Whitethroat (*S curruca*) 3 Garden Warbler *S hortensis* Whitethroat (*S cinerea*) 5 Blackcap *S atricapilla*)

Common British forms are the Song-Thrush (*Turdus musicus*), Fieldfare (*T. pilaris*), and Blackbird (*T. merula*), all of which are widely distributed in Europe, Asia, and North Africa.

The remaining native thrushes and thrush-like birds are:—Redwing (*Turdus iliacus*); Ring-Ousel (*T. torquata*); Missel-Thrush (*T. viscivorus*); Red-spotted Bluethroat (*Cyanecula suecica*); Nightingale (*Daulias luscinia*); Robin Redbreast (*Erithacus rubecula*); Whinchat (*Pratincola rubetra*); Stonechat (*P. rubicola*); Wheatear (*Saxicola œnanthe*); Redstart (*Ruticilla phœnicurus*); Black Redstart (*R. tithys*).

Warblers (fig. 108) are smaller and slenderer birds than thrushes, and more insectivorous in their habits. There is not the same difference of plumage between young and adult birds as in thrushes. Though the group is cosmopolitan, it is essentially characteristic of the Old World.

Fig. 109.—Golden-crested Wren (*Regulus cristatus*) below; Fire-crested Wren (*R. ignicapillus*) above.

Among the numerous British species may be mentioned:—Whitethroat (*Sylvia cinerea*); Golden-crested Wren (*Regulus cristatus*), the smallest of European birds) (fig. 109); Sedge Warbler (*Acrocephalus phragmitis*); and Hedge-Sparrow (*Accentor modularis*).

Our remaining species of warblers are:—Lesser Whitethroat (*Sylvia curruca*); Blackcap Warbler (*S. atricapilla*); Garden Warbler (*S. hortensis*); Dartford Warbler (*S. undata*); Marsh Warbler (*Acrocephalus palustris*); Reed Warbler (*A. streperus*); Grasshopper Warbler (*Locustella nævia*); Chiffchaff (*Phylloscopus rufus*); Wood-Wren (*P. sibilatrix*); Willow-Wren (*P. trochilus*); Fire-crested Wren (*Regulus ignicapillus*) (fig. 109).

17. *Wrens*, properly so called, are small birds with fairly long, straight, or nearly straight, beaks and rounded wings. The tail is usually carried bent up over the back. Commonest in South America, these birds are also found in North America, Europe and some parts of Asia.

The Common Wren (*Troglodytes parvulus*) of Britain is

essentially an European bird, but is also found in South-west Asia and parts of North Africa.

18. *Swallows* are cosmopolitan birds with remarkable powers of flight. The beak is short and broad at the base, the feet weak, the wings very long and pointed, and the tail generally forked. The food consists of insects, which, as is well known, are caught on the wing.

The three British species are the Swallow (*Hirundo rustica*), the House-Martin (*Chelidon urbica*), and the Sand-Martin (*Cotile riparia*). All three have a wide distribution in Europe, Asia, and Africa, while the Sand-Martin also ranges from the north of North America as far south as the Amazon valley.

19. *Lyre-Birds*, remarkable for the shape assumed by the tail of the male, have no very near allies. They are only found in South and East Australia.

Order 2.—Picarian Birds (*Picariæ*)

This large order resembles that of the perching birds in many respects, but is distinguished by slight anatomical differences of too technical a nature to be given here. Most members of the group lay white eggs in holes or other places likely to escape observation.

Among other families, those of 1. Woodpeckers, 2. Toucans, 3. Cuckoos, 4. Humming-Birds, 5. Swifts, 6. Night-Jars, 7. Hoopoes, 8. Hornbills, and 9. Kingfishers, may be more especially noticed.

1. *Woodpeckers.*—These are tree-climbing birds, in which the fourth toe is turned back parallel to the first (zygodactyle type of foot), while the strong chisel-shaped beak is used both in the pursuit of insects and to dig out holes for nesting purposes. The long worm-like tongue, which, covered by a sticky secretion, is used to capture insects, can be protruded to a considerable distance, and the related muscles and bones are specially modified, as will be described elsewhere. The young are helpless. Woodpeckers range over the entire globe, with the exception of Australasia.

There are three British species, of which the best known is the Green Woodpecker (*Gecinus viridis*), a form which is distributed over most of Europe, and also ranges into Asia Minor

and Persia The other two are the Great Spotted Woodpecker (*Dendrocopus major*) and the Lesser Spotted Woodpecker (*D minor*)

2 *Toucans* are South American birds, distinguished by exceedingly gay plumage and an enormous flattened bill, which also is brightly coloured Their feet are zygodactyle

3 *Cuckoos* are long tailed birds, with feet like those of woodpeckers, the fourth and first toes being turned backwards

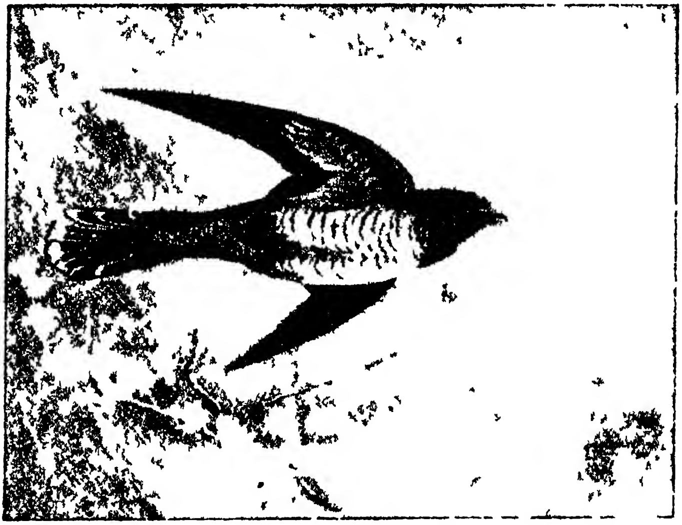


Fig 110 —Cuckoo (*Cuculus canorus*)

They range over most of the globe but their head quarters are in tropical regions Most of the Old World species lay their eggs in the nests of other birds but the New World species build nests of their own

The Common Cuckoo (*Cuculus canorus*) (fig 110) which is a British resident from April to August (though the young birds may stay later), somewhat resembles a hawk in appearance, and is often taken for such not only by human beings but also by small birds The familiar cry is uttered by the male only, the note of the female being quite different. It may be interesting to remark that the "cuckoo" call is only possessed by this species and by a South African form (*Cuculus gularis*). The common cuckoo ranges over most of Europe, Africa, and Asia.

4. *Humming-Birds*, remarkable for their small size, remarkable powers of flight, and, as a rule, the metallic brilliancy of their plumage, range from Mexico to the extreme south of South America The beak in the adult is long and slender, and the tongue has an elaborate mechanism for pushing it out and pulling it back, much as in woodpeckers Only the first toe is turned backwards

5 *Swifts* are swallow-like birds with very long pointed wings, conferring considerable powers of flight. The short beak is broad at its base, and the mouth is consequently wide. A swift can easily be distinguished from a swallow by counting the tail-quills, which are ten in number instead of twelve. The distribution is world wide, if New Zealand be excepted.

The Common Swift (*Cypselus apus*) of the British Isles is a summer visitor which nests in holes in roofs, walls, &c With the exception of a light patch under the chin, it is of a blackish colour, the tail forked, and the exceedingly small feet have all four toes directed forwards This species ranges over the greater part of the Old World

6 *Night Jars* or *Goat Suckers* are mottled forms with broad beaks like those of swifts, and hair like feathers in the neighbourhood of the mouth The spotted eggs are laid in open places, and the young are thickly covered with down. Members of the group are found in all parts of the world, except New Zealand and some of the islands of the Pacific

Fig 111 —Hoopoe (*Upupa epops*)

The European Night-Jar (*Caprimulgus Europæus*) is found in these islands from mid-May till September or it may be later. Its range includes most of Europe and Africa and South-west Asia.

7. *Hoopoes* in many respects resemble the perching birds,

with which they are often included. The well-developed first toe is turned backwards. They are essentially desert forms, and their beautiful plumage is coloured so as to largely harmonize with surroundings of the kind. The head is distinguished by its long slender curved beak and handsome crest of features, which can be raised or depressed at will.

Fig. 112.—Rhinoceros Hornbill (*Buceros rhinoceros*)

The European Hoopoe (*Upupa epops*) (fig. 111) is a fairly common visitor to Britain.

8. *Hornbills* (fig. 112) are large tropical birds, ranging from Africa to the Solomon Islands, and distinguished by the possession of enormous beaks, which in some cases have a large projection or casque on the upper side at the base.

9. *Kingfishers* are distinguished by the structure of their feet in which the great toe is backwardly directed, and the two outer toes united together. The beak is strong and pointed, varying in shape according to the food, which in one group consists of fish, in the other of reptiles and small mammals. Kingfishers have a world wide distribution, but are most abundant in the Australian half of the East Indies, from Celebes to New Guinea, to which area the majority of the genera are confined.

The European Kingfisher (*Alcedo ispida*), which is a well-known British resident, is distinguished by its beautiful plumage, in which various shades of blue predominate above while the under surface is chestnut-coloured. As in the fish eating species generally, the beak is long and pointed, while the tail is short. As an example of the reptile-eating kingfishers, the Laughing

Jackass (*Dacelo gigantea*) (fig. 113) of Australia and New Guinea may be taken. Here the beak is broader and stronger, and the tail is longer than in fish-eating forms.

Order 3.—Owls (*Striges*)

Here are included birds of prey, which are mostly nocturnal, and of characteristic appearance mainly due to the large forwardly-directed eyes surrounded by discs of radiating feathers. The four toes of the strong feet are all provided with sharp claws, and the fourth toe is reversible, being turned forwards or backwards at will. In flight these birds are peculiarly noiseless their plumage being extremely soft. The young are helpless. Owls are universally distributed, and in all countries are regarded with awe by the superstitious, which is no doubt the result of their peculiar appearance and habits, aggravated by a most unearthly voice.

Fig. 113.—Laughing Jackass *Dacelo gigantea*

The most familiar British form is undoubtedly the Barn-Owl (*Strix flammea*), which is almost as universally distributed as the order to which it belongs. Other well-known native forms are the Tawny or Wood-Owl (*Syrnium aluco*), the "hoot" of which is a familiar country sound, the Long-eared Owl (*Asio otus*), and the Short-eared Owl (*Asio accipitrinus*). The "ears" of the last two kinds are tufts of feathers on the top of the head. The large Snowy Owl (*Nyctea Scandiaca*) regularly visits North Scotland during the winter.

The largest members of the group are the Great Horned or Eagle-Owls, of which the Great Eagle-Owl (*Bubo ignavus*) is sometimes caught in Great Britain, while the Pigmy-Owls are the smallest, being little more than half the size of the Barn-Owl. Interesting modifications of habit are found in the Hawk-Owl (*Surnia ulula*) of North Europe and Asia, which hunts its prey during the day; the Fish-Owls of Africa and South Asia, which frequent the neighbourhood of streams and lakes; and the little Burrowing-Owl (*Speotito cunicularia*) of America, which lives in the burrows excavated by rodents.

Order 4.—Parrots (*Psittaci*)

Parrots and the like constitute a large and well-marked group, the characters of which are familiar to almost everybody. The beak is short, stout, and hooked, a remarkable feature being that the upper jaw can be moved up and down as well as the lower jaw. A prominent cere is present. The legs are short and strong, while the feet are modified to serve as climbing organs, the fourth as well as the first toe being turned permanently backwards. The hooked beak is also used in climbing. The young birds are hatched in a helpless condition. The group is essentially tropical and sub-tropical, and is most abundantly represented, as regards number of species, in Australasia, from Celebes eastwards; while in abundance of individuals South America stands pre-eminent.

Probably the most familiar form is the common Grey Parrot (*Psittacus erithacus*) of Equatorial Africa. Its short square-ended red tail is distinctive. The *Cockatoos*, distinguished by their crests, are natives of Australia and the eastern Malay Islands, ranging also into the Philippines. The gorgeous long-tailed *Macaws* range from South America into Mexico, while the little *Love-Birds* are limited to Madagascar and Africa south of the Sahara. The *Parrotlets* are diminutive South American forms. Two small and peculiar families of parrots are confined to New Zealand and the neighbouring islands. One of these includes the Nestor-Parrots, of which the form known as the Kea (*Nestor notabilis*) has earned an evil reputation by its acquired habit of preying on sheep. The other family is constituted solely for the reception of the Kakapo or Owl-Parrot (*Stringops habroptilus*),

LEADBEATER'S COCKATOO (*Cacatua Leadbeateri*)

Cockatoos (*Cacatuidæ*) are among the most typical birds of the Australasian region, from Celebes to the Solomon Islands, and also ranging north to the Philippines They are absent from New Zealand The erectile crest and short broad tail are characteristic features

The beautiful species figured is native to South Australia, and is of unusually large size, attaining the length of 16 inches

LEADBEATER'S COCKATOO (CACATUA LEADBEATERI)

which has lost the power of flight and lives on the ground. The owl-like appearance is due to slender radiating feathers round the eye.

Order 5.—Pigeons and Sand-Grouse (Columbæ)

The description already given of a pigeon (p. 139) will give a good idea of the appearance and structure of the birds of this order.

Pigeons and *Doves* are distributed over the entire globe, but the largest number of peculiar genera and species are found in the southern land masses, especially Australia.

British species are the Rock Dove or Blue-Rock (*Columba livia*), the Ring-Dove, Wood-Pigeon, or Cushat (*C. palumbus*), the Stock-Dove (*C. œnas*), and, as a summer visitor, the Turtle-Dove (*Turtur communis*). Probably the most striking of exotic forms, and the largest members of the group, are the Crowned Pigeons of Australasia (fig. 114).

Fig 114.—Crowned Pigeon (*Goura*)

Sand-Grouse are essentially desert birds, and are quietly coloured to harmonize with their surroundings. Their head-quarters are Africa and Central Asia, also extending into South-west Europe and into India. Their unusually short legs and toes prevent them from perching, but the wings are long and pointed, conferring great powers of flight. The tail is also pointed. Some naturalists place these birds in a special order, and they have affinities with game-birds as well as pigeons, as shown by the structure of their digestive organs and the fact that their young are precocious.

Pallas's Sand-Grouse (*Syrrhaptes paradoxus*) inhabits, during summer, the steppes between the Caspian and Lake Baikal, migrating farther east in winter, and from time to time invades Europe in smaller or larger flocks, penetrating as far west as the British Isles.

Order 6.—GULLS (Gaviæ)

In many respects these birds resemble the plovers, and like them are cosmopolitan, and have precocious young. They differ, however, in being adapted to a marine life, as seen especially in the fact that the three front toes are connected by a web It may also be noted that the plumage is entirely or largely light in colour.

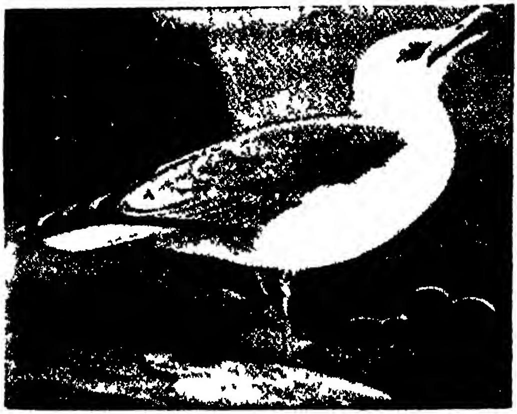


Fig 115 —Herring Gull (*Larus argentatus*)

Well-known British types are the Common Tern (*Sterna fluviatilis*), the Common Gull (*Larus canus*), the Herring-Gull (*Larus argentatus*) (fig. 115), and the Kittiwake (*Rissa tridactyla*).

The other British gulls, &c., are:—Lesser Black-backed Gull (*Larus fuscus*); Great Black-backed Gull (*L. marinus*); Glaucous Gull (*L glaucus*), Iceland Gull (*L. leucopterus*); Little Gull (*L. minutus*); Black-headed Gull (*L. ridibundus*), Sandwich Tern (*Sterna Cantiaca*); Roseate Tern (*S Dougalli*), Arctic Tern (*S. macrura*); Little Tern (*S. minuta*); Black Tern (*Hydrochelidon nigra*), Common Skua (*Stercorarius catarrhactes*) (fig. 117); Richardson's Skua (*S crepidatus*), Long-tailed Skua (*S. parasiticus*), Pomatorhine Skua (*S. pomatorhinus*)

Order 7.—PLOVERS (Limicolæ)

Here are included birds with long pointed wings and long legs. The toes are not as a rule webbed, and the first toe is very small. Young precocious. The distribution is world-wide.

They include Plovers, Curlews, Phalaropes, Sandpipers (fig. 116), Woodcock, Snipe, &c.

British types are the Golden Plover (*Charadrius pluvialis*) (fig. 117), the Lapwing or Peewit (*Vanellus cristatus*), distinguished by its handsome crest and peculiar wailing cry, the

Fig 116.—Sandpipers (*Totanus*)

Woodcock (*Scolopax rusticula*), and the Common Snipe (*Gallinago cœlestis*), both these last possessing long, straight, slender beaks.

The remaining British species are:—Stone Curlew (*Œdicnemus scolopax*), Pratincole (*Glareolus pratincola*); Ringed Plover (*Ægialitis hiaticula*); Kentish Plover (*Æ. Cantiana*) Dotterel (*Eudromias morinellus*); Oyster Catcher (*Hæmatopus ostralegus*); Grey Plover (*Squatarola Helvetica*), Turnstone (*Strepsilus interpres*); Sanderling (*Calidris arenaria*), Bar-tailed Godwit (*Limosa Lapponica*), Black-tailed Godwit (*L. Belgica*); Great Snipe (*Gallinago major*); Jack Snipe (*G. gallinula*); Ruff (*Machetes pugnax*); Curlew (*Numenius arquata*); Whimbrel (*N. phæopus*); Grey Phalarope (*Phalaropus fulicarius*) (fig. 117); Red-necked Phalarope (*P. hyperboreus*); Common Sandpiper (*Totanus hypoleucus*); Wood Sandpiper (*T. glareolus*); Green Sandpiper (*T. ochropus*); Dunlin (*Tringa alpina*); Knot (*T. canutus*); Little Stint (*T. minuta*); Sharp-tailed Sandpiper (*T. acuminata*); Purple Sandpiper (*T. striata*); Curlew Sandpiper (*T. subarquata*); Temminck's Sandpiper (*T Temmincki*).

Order 8.—Bustards and Cranes (Alectorides)

This is a somewhat artificial assemblage of forms which agree in many respects with the game-birds, differing, however, in minor anatomical characters. The young are precocious.

Bustards are thick-set birds common in the open parts of

Fig 117.—Skuas (*Stercorarius*), Phalarope (*Phalaropus*), and Golden Plovers (*Charadrius*) (from left to right)

the Old World, including Australia. The Great Bustard (*Otis tarda*) was formerly abundant in Britain, but is now only an occasional visitor. The male possesses curious white "whiskers" made up of hair-like feathers.

Cranes resemble herons and storks in their general appearance, but are distinguished from them by a number of characters, one being that the short first toe is raised a little off the ground. Further, the young are precocious instead of being helpless. The Common Crane (*Grus cinerea*) (fig. 118) is now only seen wild in Britain as a rare visitor, but 300 years ago was common. It ranges over most of Europe, North Africa, and Asia.

Order 9.—Rails (Grallæ)

These cosmopolitan birds are closely allied to those of the following order, but are of more slender build, with feebler wings, shorter tail, and less compact plumage. Many of the species have lost the power of flight.

Common British examples are the Land-Rail or Corn-Crake (*Crex pratensis*), the peculiar creaking call of the male being a

Fig 118.—Common Crane (*Grus cinerea*). (From an instantaneous photograph)

familiar sound on summer evenings, the Water-Rail (*Rallus aquaticus*), the Moor-Hen (*Gallinula chloropus*), and the Coot (*Fulica atra*). The toes of the last-named species are lobed. The Spotted Crake (*Porgana marnetta*) also occurs in this country.

Order 10.—Game-Birds (Gallinæ)

One has only to think of the appearance of ordinary fowls to realize the leading characteristics of this order. The body is plump and supported on strong legs adapted for rapid progression, and provided with strong claws suitable for scratching up the ground. The neck is fairly long, and the rounded head is provided with a strong beak, the upper half of which projects beyond the lower. The young are precocious, and soon able to look after themselves.

All the various domestic breeds of fowls, despite their extreme diversity in appearance, would appear to be descendants of the Red Jungle-Fowl (*Gallus Bankiva*), a species which ranges across North India from Kashmir to Assam, and also extends farther east as far as the Philippines. In general appearance these birds much resemble game-fowls, and, like their tame relatives, possess a notched fleshy comb, and a pair of wattles hanging from the throat.

Jungle-fowl are closely related to the *Pheasants*, which have a wide range in the Old World. The common Pheasant (*Phasianus Colchicus*) is not a native of this country, but of Asia Minor and South-east Europe. Other species extend the distribution of the group to East Asia, which must be considered its head-quarters. The male bird, as in so many other cases, is much more brightly coloured than the female, and this difference is emphasized in many exotic forms, as particularly in the Gold and Silver Pheasants (*Chrysolophus pictus* and *Gennæus nycthemerus*), both of which are natives of Eastern Europe.

Conspicuous among domesticated game-birds in this country are the Peacock (*Pavo cristatus*), found native in India and Ceylon, Guinea-Fowl (*Numida meleagris*), belonging, as the name indicates, to West Africa, and the Turkey (*Meleagris gallopavo*), from the southern parts of North America.

Other well-known inhabitants of Britain are: Partridge (*Perdix cinerea*); Red-legged or French Partridge (*Caccabis rufa*), intro duced about a century ago; Quail (*Coturnix communis*); Capercailzie (*Tetrao urogallus*); Black Grouse (*Lyrurus tetrix*); Red Grouse (*Lagopus Scoticus*); and Ptarmigan (*L. mutus*), the last being remarkable for the changes of plumage exhibited at differ- seasons of the year.

The Red Grouse deserves special mention, for with the exception of certain fresh-water fishes, it is the only vertebrate species peculiar to Britain.

Order 11.—TINAMOUS (Crypturi)

This is a small group of South American birds which are locally called "partridges", a name which at once suggests their general appearance and size. Though, however, appearing to have certain points in common with game-birds, they are also allied to flightless birds (ostriches, &c.), as is evidenced by the structure of the skull and by the much-reduced tail, the quills of which are not supported by a plough-share-bone resulting from the fusion of the last few vertebræ (see p. 144).

Fig 119—Peregrine Falcon (*Falco peregrinus*

Order 12. EAGLES and VULTURES (Accipitres)

It has been a frequent practice to associate together as "birds of prey" eagles, vultures, owls, and their allies; but the association, like many others founded mainly on habit, is an artificial one, and it is now considered better to make two groups of such birds. The one under consideration includes those forms which hunt their prey in the daytime. The beak is hooked and the toes are furnished with formidable talons, but the great toe is not reversible as in owls, being permanently directed backwards. The plumage is compact, and the eyes face to the side.

Four groups are here included—Falcons, vultures, American vultures, and secretary-birds.

Falcons.—Most of these forms pursue living prey, while both head and neck are as well provided with feathers as the other parts of the body.

As a type of the true falcons, the Peregrine Falcon (*Falco peregrinus*) may be taken, and this form is of particular interest on account of its former use in hawking. The head and upper side of the body are dark, and the under side light with black barrings (fig. 119). The short beak is notched at the sides, and the legs and cere are yellow. It ranges through Europe and away to Japan in the east and North-east Africa in the south.

The Kestrel or Windhover (*Falco tinnunculus*) is a familiar species closely related to the preceding, but much smaller. Its range is similar.

The remaining British Falcons are:—Merlin (*Falco æsalon*); Hobby (*F. subbuteo*); Red-footed Falcon (*F. vespertinus*).

Another group closely related to the true falcons is that of eagle-like birds, including not only eagles, but also kites, buzzards, hawks, and harriers. The eagle par excellence is the Golden Eagle (*Aquila chrysaëtus*), of which the eyries are still to be found in the Highlands and along the west and north of Scotland, while a few are to be seen on the west coast of Ireland. Its geographical range is very considerable, including Europe, North Asia, North Africa, and the greater part of North America. We have also the White-tailed Eagle (*Haliaëtus albicilla*). The Crowned Harpy (*Harpyhaliaëtus coronatus*) is a crested eagle, widely distributed in South America.

A familiar example of the smaller eagle-like birds is the rapacious Sparrow-Hawk (*Accipiter nisus*), which is common in the well-wooded parts of Britain. Long-legged and slender in its proportions (fig. 120), this bird is otherwise not unlike a falcon as regards the character and markings of the plumage, but is distinguished by shorter wings, more gently curving beak devoid of notches at the side, and a peculiarly dashing flight. The female Sparrow-Hawk destroys more game than any other native bird of prey. As to range, this form extends throughout Europe, North Asia, and North Africa, while allied species are found in most parts of the globe.

The other eagle-like birds of Britain are:—Common Buzzard (*Buteo vulgaris*); Rough-legged Buzzard (*B. lagopus*); Marsh Harrier (*Circus æruginosus*); Montagu's

RÜPPEL'S VULTURE (*Gyps Ruppeli*)

This powerful bird is an inhabitant of the Western Soudan. Its strong hooked beak and well developed talons show it to be a bird of prey, while the bare neck is characteristic of the group of Vultures to which it belongs In tropical countries dead animals begin to putrefy very rapidly, and would constitute a serious nuisance were there not some natural provision for their speedy removal Vultures are typical scavengers, the bare necks of these creatures are an obvious adaptation to their nauseous but useful habits.

RUPPEL'S VULTURE (GYPS RUPPELI)

A STUDY FROM THE LIFE

Harrier (*C. cineraceus*); Hen Harrier (*C. cyaneus*), Kite (*Milvus ictinus*); Osprey (*Pandion haliaetus*); Honey Buzzard (*Pernis apivorus*).

Vultures.—Here are included large birds which for the most part feed on carrion, and therefore play an important part in nature as scavengers, in accordance with which habit the head and neck are as a rule devoid of plumage, or only provided with short stiff feathers. The long beak is sharply bent down at the tip, and there is a large cere. These birds are common in the warm parts of the Old World.

A well-known species is the Black Vulture (*Vultur monachus*), which ranges from the European and African shores of the Mediterranean to India and China in the east. Its beak is black, like its plumage, while the bare head and neck are flesh coloured, the latter being further distinguished by a peculiar ruff of feathers, as commonly is the case in birds of the group. Another typical form is Ruppel's Vulture (*Gyps Ruppelii*), a native of North Africa.

Fig. 120. Sparrow Hawk (*Accipiter nisus*).

American Vultures differ in a number of respects from those of the Old World, as particularly in the absence of a syrinx (the organ of voice specially characteristic of birds), and the lack of a partition between the right and left nostrils. To this group belongs the largest of living flying birds, the Condor (*Sarcorhampus gryphus*) of the Andes, in which the spread of the wings may be as much as 9 feet. The shining black plumage is relieved by a white neck-ruff, and by white and grey shading on the wings. In the male there is a fleshy outgrowth or wattle on the top of the head. These birds, though mainly carrion feeders, also prey on living animals.

Secretary-Birds.—The only representative of the last group of diurnal birds of prey is the well-known Secretary-Bird (*Serpentarius secretarius*), which ranges from South Africa far north along both sides of the continent. In general appearance it looks like a modified eagle mounted on stilts, and may exceed 4 feet in height. The naturally long tail is made still longer by the great extension of its middle pair of quills, and projecting backward from the head on each side is a loose crest which suggesting a bundle of quill pens carried above the ear, has given rise to the popular name. The plumage on the head, neck, and front part of the body and wings is mostly light-grey, but the top of the head, with the crests, the quills (except the middle pair of the tail), the abdomen, and the tops of the legs, are much darker in hue.

Secretary-Birds feed on reptiles, small mammals, and game birds.

Order 13.—Ducks, Geese, and Flamingoes (Anseres)

In this large order the large bill is usually broad and flattened, and the three front toes are united by a web. The young are "precocious", *i.e.* able to run about and feed themselves almost at once, as is familiarly illustrated by the case of the duckling. Species belonging to the order are found in all parts of the world.

Ducks and *Geese.*—These are short-legged birds with broad straight bills and smooth plumage which easily sheds the water. They are essentially adapted to an aquatic life, and their clumsy movements on land are familiar to all. A common type is the British Wild Duck (*Anas boschas*), from which our domesticated varieties are derived. The brilliant colouring of the drake is too familiar to need description. This species ranges over the whole of the Northern Hemisphere. *Shoveller Ducks* are distinguished from other ducks by the peculiar shape of their unusually large bills. The Common Shoveller (*Spatula clypeata*) is a winter visitor in Britain. Among other British ducks, Teal (*Querquedula quetta*), Widgeon (*Mareca penelope*), and Eider Ducks (*Somateria mollissima*) may be mentioned here.

The remaining native ducks are:—Pintail (*Dafila acuta*); Tufted Duck (*Fuligula cristata*); Pochard (*F. ferina*); Golden-eye Duck (*F. glaucion*); Scaup (*F. marila*); Ferruginous Duck (*F. nyroca*); Long-tailed Duck (*Harelda glacialis*);

Smew (*Mergus albellus*), Goosander (*M merganser*), Red breasted Merganser (*M serrator*), Velvet Scoter (*Œdemia fusca*), Black Scoter (*Œ nigra*), Sheldrake (*Tadorna cornuta*)

Geese are heavier and clumsier birds than ducks, and there is a curious knob on the tip of the bill The domestic form is in all probability descended from the Grey lag Goose (*Anser cinereus*) (fig 121) which breeds only in Britain and ranges from our islands throughout Europe and as far east as China The Egyptian Goose (*Chenalopex Ægyptiacus*) was domesticated by the ancient Egyptians, who much appreciated it as an article of diet as is attested by sculptures

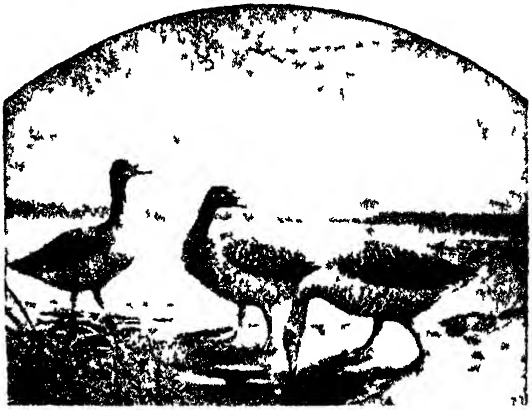


Fig 121 —Grey lag Goose (*Anser cinereus*)

Other British geese besides the Grey lag are —White fronted Geese (*Anser albifrons*) Pink footed Geese (*A brachyrhynchus*), Bean Geese (*A segetum*), Brent Geese (*Bernicla brenta*), Bernicle Geese (*B leucopsis*)

Swans are large birds related to the geese but distinguished by their long slender necks and shorter bills The common White or Mute Swan (*Cygnus olor*) is distributed through Europe and also ranges into Asia and North Africa We have also Bewick's Swan (*C. Bewicki*) and the Whooper (*C musicus*) Remarkable species as regards colour are the Black Swan (*Cygnus atratus*) of Australia and the Black necked Swan (*Cygnus nigricollis*) of the southern parts of South America

Flamingoes are large birds which give a general impression of swans mounted on storks' legs but are peculiar in regard to the beak, which is very large and bent sharply downwards for the greater part of its extent The species are not very numerous, but have a wide distribution, being absent however, from the colder regions of the globe and from Australia The Common

Flamingo (*Phœnicopterus roseus*), like all its allies, is distinguished by the prevailing red colour of the plumage, the predominant shade in this case being rose-pink relieved by the black wing-quills and scarlet wing-coverts. The black-tipped beak is otherwise rose-coloured, as are the legs and feet. This particular species ranges from the south of France and Spain eastwards to Siberia and India, and southward to the Cape.

Order 14.—Herons and Storks (Herodiones)

The birds of this order are long-legged waders with powerful wings and long strong pointed beaks. The feet are either not

Fig. 122. Herons and their Nests

webbed at all or only partially so, and in the latter case the great toe is always free. The order includes the groups of herons, storks, and ibises.

Herons (fig. 122).—These are slenderly-built birds with narrow beak, and in most cases a slender neck. The wings are large but blunt-tipped, and there is a curious patch of "powder

down" feathers on each side of the rump, *i.e.* of downy feathers the tips of which readily crumble into powder. The plumage is somewhat loose, and the head or adjacent parts are often crested. Herons are mostly found in marshy places, preying upon fish, or it may be other small animals. Though commonest in tropical and subtropical regions, they are also widely distributed elsewhere, and are best known in Britain as represented by the Common Grey Heron (*Ardea cinerea*), the unfortunate bird which was the chief victim of the ancient sport of falconry. This species ranges eastwards to Japan, and southwards to the Cape. Bitterns and Boat-billed Herons are other members of the group.

Besides the Grey Heron, we have in Britain:—Common Bittern (*Botaurus stellaris*); Little Bittern (*Ardetta minuta*); Night Heron (*Nycticorax griseus*).

Storks.—These are not so slenderly built as herons, and do not possess the patches of powder-down feathers. The three front toes are connected together at their bases by a small web. Like herons, they haunt swamps and inland waters, feeding largely on frogs, and their distribution is equally wide.

The White Stork (*Ciconia alba*) is found in most parts of Europe, from which it ranges into North Africa, Central Asia, and India. This bird is a familiar object on the Continent, enjoying for the most part immunity from human attack, and nesting on chimneys, the gable-ends of buildings, &c. It plays a large part in fairy tales and stories, as everyone knows who has read "Andersen's Fairy Stories", and who has not? All will remember that the Stork is supposed to bring the new brothers and sisters, as witness the story of the irreproachable Peter, whose invocations to this invaluable bird were rewarded by the appearance of a brother and sister at the same time. Closely related to ordinary storks are the large, ungainly Adjutants or Marabout Storks of Africa and India, with enormous bills. They feed not only upon small living animals, but also on carrion, and in accordance with this habit the head is destitute of ordinary feathers.

Ibises.—Smaller than the average members of the preceding groups, these birds possess beaks which are only hard at the tip. Their wings are pointed and their tails abbreviated. In habits and distribution they are very similar. The best-known species is the African Ibis (*Ibis Æthiopica*) (fig. 123), which

was venerated and embalmed by the ancient Egyptians, and which, with its long curved beak and bald black head and neck contrasting with the generally white plumage, is a striking object. Its head-quarters are now the upper waters of the Nile, from which it ranges with diminishing numbers to Cape Colony. A beautifully-coloured form is the Scarlet Ibis (*Guara rubra*) of tropical America and the West Indies, in which the plumage is bright scarlet except the wing-tips, which are black.

Fig. 123.—African Ibis (*Ibis Æthiopica*)

The widely distributed *Spoonbills* are closely related to the Ibises, but are distinguished by the peculiar form of the broad straight beak, which widens out into a rounded end. The White Spoonbill (*Platalea leucolodia*) is a common European bird which also ranges into North Africa and eastward to India and North China. It is but rarely seen in our own country. The beak and legs are black and the plumage prevailingly white.

Order 15.—Pelicans and Cormorants (Steganopodes)

This order of swimming birds includes short-legged forms in which all four toes are well developed and connected together by a web. The wings and tail are large, and the organization is adapted for the pursuit of fish. Four groups are here included: Pelicans, Cormorants, Frigate-Birds, and Tropic-Birds.

Pelicans.—These well-known birds are distinguished by their enormous flattened beaks, to the lower half of which is attached a large pouch in which fish can be stored. "Feeding time" with the Pelicans is one of the favourite spectacles of interest

at the Zoo. The group is widely distributed in the warmer parts of the globe, and its members haunt the banks of rivers and the neighbourhood of swamps. The best-known species is the European Pelican (*Pelecanus onocrotalus*), which is found not only in South Europe, but North Africa, and also in parts of West Africa.

Cormorants. – These are smaller birds than the pelicans, and are characterized by their long bodies and necks and the possession of a moderately long beak, rather narrow, and hooked at its tip. Both face and throat are bare of feathers. Cormorants are excellent divers and swimmers, and their greediness is extreme. Two species are well known in British seas. One, the Black Cormorant (*Phalacrocorax carbo*), has an extraordinarily wide range, including all Europe, North Africa, most of Asia, and the Atlantic shores of North America. The other British species is the Green Cormorant or Shag (*P. graculus*). The Chinese and Japanese train cormorants to fish for them, and, until properly trained, a ring is put round the neck to prevent the captures from being swallowed.

Other birds related to the cormorants are *Gannets* and *Darters*. Of the former the most familiar type is the Common Gannet (*Sula bassana*), found on the coasts of the northern seas, and breeding in vast numbers at one locality on the east coast of Britain, the Bass Rock. The Scottish name for this bird is the Solan Goose, a name which suggests its general appearance, though about the neck and head it is much more like a cormorant. The head and neck are buff-coloured and the wing-tips black, but otherwise the plumage is white. The "boobies", so named from their fearlessness, of which we read in accounts of voyages to southern seas, are closely allied to gannets.

Darters or *Snake-Birds* are a small group with exceedingly long flexible neck, small head, and long, extremely sharp-pointed beak. The legs are attached far back to the elongated body. These forms haunt the inland waters of South America, Africa, India and Further India, and Australia.

Frigate and *Tropic Birds* are both distinguished by their pelagic habits, *i.e.* they are commonly found in the open sea at great distances from land. Each group contains but a single genus, and the distribution is similar, as both of them are found in the warmer parts of the Atlantic, Pacific, and Indian Oceans.

The Great Frigate-Bird (*Fregatus aquila*) is a striking object, with its long, hooked beak, powerful wings, and forked, swallow-like tail. The legs are extremely short, and feathered to the toes, which have but an imperfect web. The dark plumage of the male is relieved by a bright-reddish throat Tropic-Birds are well known from their habit of following ships. They are

Fig 124 —Albatross (*Diomedea exulans*)

small and light-hued, differing from Frigate-Birds in the shape of the beak, the complete webbing of the toes, and the nature of the tail, of which the two middle quills are much elongated The commonest species is the Red-beaked Tropic-Bird (*Phæthon æthereus*), prevailingly white in colour, but with a coral-red beak.

Order 16.—Petrels and Albatrosses (Tubinares)

The birds of this order are good swimmers, and have webbed feet not unlike those of the next two orders. They are essentially marine, and have a wide distribution, being commonest, however, in the seas of the southern hemisphere. The members of the group are distinguished by being "tube-nosed", *i.e.* the nostrils

open upon a pair of forwardly-directed tubes. All are powerful flyers, and their food consists of fish, various small marine animals, and refuse of various kinds. The strong beak, with sharp, hooked tip, is well adapted to the carnivorous habit.

The Wandering Albatross (*Diomedea exulans*) (fig, 124), distinguished by its enormous spread of wing (10 to 12 feet), and

Fig 125.—Great Auk (*Alca impennis*)

found chiefly in southern seas, is immortalized in Coleridge's *Ancient Mariner*. Almost as well known is the Storm Petrel (*Procellaria pelagica*) of the North Atlantic, called "Mother Carey's Chicken" by sailors. It is only 6 inches long, and is the smallest web-footed bird found in British seas.

Order 17.—Divers and Grebes (Pygopodes)

The diving birds are distinguished by the modifications they have undergone to enable them to pursue fish. In accordance

with this, the short legs are attached to the body extremely far back, and the feet are either webbed or the toes are broadened out into lobes. As in a pigeon, there are three forwardly-directed digits, but the great toe, instead of being well-developed, is either small or absent, not being required in birds which are not in the habit of perching on branches and the like. The wings are comparatively short, and are useful not only as organs of flight, but to assist the animal in swimming. The straight beak is more or less flattened from side to side. Auks, Divers, and Grebes are included in this order. Of the first group perhaps the most interesting is the Great Auk, or Gare-Fowl (*Alca impennis*) (fig. 125), which is unfortunately extinct, the last specimens having been shot in 1844. It formerly occurred in great numbers on some small Icelandic islands, and Funk Island, near Newfoundland, to which localities it largely resorted for breeding purposes. Its small wings were useless for the purposes of flight, a fact which had much to do with its extinction. All the remaining flightless birds are limited to the southern hemisphere. The nearest living relative of the Great Auk is the Common Razorbill (*Alca torda*) (fig. 126), which is common in British seas and has a wide range along both shores of the North Atlantic. Near the Auks come the *Guillemots*, with narrower and straighter beaks. The type form is the Common Guillemot (*Uria troile*), which has a similar distribution to the Razorbill. Much more peculiar forms are the *Puffins*, called "sea parrots" from the shape of their exceedingly large and laterally-compressed bills. The Common Puffin (*Fratercula arctica*) is the only kind found in British waters, and has a winter range from the Arctic regions to the Tagus on the eastern shore, and to New York on the western shore, of the Atlantic. The orange-coloured beak, shading into red at the tip, and the white plumage covering the breast and sides of the head, make this bird a conspicuous object.

Other British Auks are:—Little Auk (*Mergulus alle*); Black Guillemot (*Uria grylle*).

The *Divers* differ from the auks in several particulars, the most obvious of which is found in the greater length and sharpness of the beak. The Great Northern Diver (*Colymbus glacialis*), which ranges from the Arctic regions to the Mediterranean and is not infrequent on British coasts, is distinguished by its black head,

throat shaded with black and white, and dark back crossed by rows of white flecks. The under side is white, as in so many birds and other animals.

There are two other British Divers:—Black-throated Diver (*Colymbus arcticus*); Red-throated Diver (*C. septentrionalis*).

Grebes resemble the preceding groups in many respects, but their toes are expanded into lobes instead of being webbed, and

Fig 126.—Razorbills (*Alca torda*)

the tail is very small, and provided with a downy tuft instead of the usual quills. The plumage of Grebes is much used for ornamental purposes, and its beauty is mainly due to the silky white feathers which cover the breast.

The most familiar member of the group in Britain is the Dabchick or Little Grebe (*Podicipes fluviatilis*), a bird which has a very wide range and is common on rivers and ponds.

Other Grebes which occur in British waters are:—Slavonian Grebe (*Podicipes auritus*); Great Crested Grebe (*P. cristatus*), Red-necked Grebe (*P. griseigena*); Eared Grebe (*P. nigricollis*).

Order 18.—Penguins (Impennes)

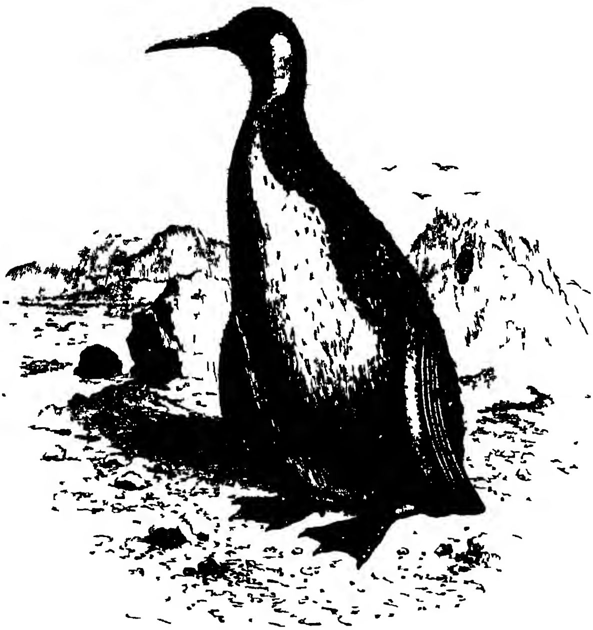
Penguins are web-footed birds with reduced great toe, resembling the divers in a number of particulars, but still better adapted to an aquatic life, as is seen especially in the wings, which are useless for the purpose of flight and are transformed into flippers covered with very numerous scale-like feathers. The hind-limbs, in which the tarso-metatarsal region is unusually short, are fixed to the body very far back, and the small tail, unprovided with efficient quills, serves as a prop by which the body is steadied in the upright position which is habitual on land. The long, straight beak, somewhat flattened laterally and with a sharp point, is well adapted for seizing and holding the fish which constitute the chief food. Penguins have a very wide range along the shores of the continents and islands south of the equator, flocks of them being abundant even on the desolate Antarctic coast. Few birds, if any, are so remarkable in appearance, and they have attracted the attention of all travellers in southern seas.

As examples may be taken the Emperor Penguin (*Aptenodytes Forsteri*) of the Antarctic regions, which is about 3½ feet high; the King Penguin (*Aptenodytes Pennanti*) (fig. 127) of Kerguelen Land; and the Blue Penguin (*Eudyptula minor*) of South Australia and New Zealand, which is less than half that size.

II. Running Birds (Ratitæ).—These birds, of which the most familiar form is the African ostrich, are mostly large, while all are flightless, this being to some extent compensated by the possession of unusual powers of rapid progression on the ground. The group is essentially one belonging to the southern hemisphere.

Inability to fly is associated with a number of structural features, foremost among which is a great reduction in the size of the wings. There are also a number of characteristic features about the plumage, which is not arranged in definite tracts as in flying birds (see p. 142). The quills, which in ordinary birds play such an important part in flight, are here much reduced, and the barbules of the feathers are not connected together by hooklets. The vertebræ of the tail are not fused together into a ploughshare-bone as in flying birds, there being no efficient tail-quills to support. The name of the group (Lat. *rates*, a raft) has reference

to the absence of a keel on the broad sternum. It will be remembered that the keel in an ordinary bird (p. 145) serves for the attachment of the large muscles of flight. There is no "merry-thought", while the scapula and coracoid are in the same line with one another instead of being at an angle. The overlap-



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ping uncinate processes which in a flying bird help to strengthen the chest, are here absent or few in number.

The strong legs are well adapted for running, and in nearly all cases there is a reduction in the number of toes.

The structure of these birds is best explained on the assumption that they are descended from carinate birds in which the power of flight has been lost, and their nearest relatives are probably the Tinamous.

The Ratitæ which are now living may be divided into African Ostriches, American Ostriches, Cassowaries and Emeus, and Kiwis.

African Ostriches are distributed through the deserts of Africa, and also range into Arabia and Syria. The small flat head is provided with a strong, broad beak, capable of being opened very widely, and large eyes surrounded with small bristly feathers resembling eyelashes. Both the head and the long neck are covered with long fluffy feathers. The legs are immensely powerful, and are used as weapons as well as for locomotion. Only two toes are present—the third and fourth, the former being much the larger, and there is a soft pad on the under side of each, much as in a camel. The plumage of the female is grey, that of the male black, except the wings and tail, which are pure white. There are no after-shafts to the feathers. The nest is simply a hollow made in the sand, and several hens lay their yellowish-white eggs in it. The work of incubation is almost entirely done by the male.

There are apparently several species of ostrich, the most familiar one (*Struthio camelus*) being distinguished by its red neck, while an East African form has a bluish neck, and this region is grey in a smaller kind from South Africa.

American Ostriches or *Rheas* are only found in South America, and can be distinguished at once by the presence of three toes, less modified than those of the African form, feather-covered head and neck, larger wings, and no tail. In structure (including the absence of after-shaft) and habits they resemble in most points the African forms, and their eggs are of similar colour. The plumage is grey, and both sexes closely resemble one another in this respect.

Three species are recognized, of which the Common Rhea (*Rhea Americana*) is largest and best known. It is commonest in the pampas region of the Argentine Republic, ranging north to Bolivia and south to the Rio Negro. Darwin's Rhea (*Rhea Darwini*) is found from the east of Patagonia to some distance north of the above-named river, while the Long-billed Rhea (*Rhea macrorhynca*) is limited to North-east Brazil.

Cassowaries and *Emeus* are to be regarded as the ostriches of the Australian region. They agree with the rheas in possessing three toes, but the wings are much reduced, the feathers appear double from the presence of very large after-shafts, and the eggs are green and rough.

The Emeu (*Dromæus*), found only on the Australian continent

THE AFRICAN OSTRICH (*Struthio camelus*)

African Ostriches are the largest living members of the group of Running Birds (Ratitæ), all of which are restricted to the Southern Hemisphere The South African variety represented is the one domesticated for the sake of its feathers, and is somewhat smaller than a variety which lives farther north African Ostriches possess but two toes, and this reduction is related to the specialization of the legs for the purpose of rapid locomotion The extinct Æpyornis, of which bones and eggs are found in Madagascar, was an immense form related to the Ostrich, and possibly the prototype of the "Roc" which figures largely in Eastern tale and legend.

SOUTH AFRICAN OSTRICHES (STRUTHIO CAMELUS)

A STUDY FROM THE LIFE

and some of its islands, resembles an ostrich in appearance, but is shorter-necked and has a slenderer body. The feathers of the head and upper part of the neck are very small, and the plumage generally is very loose, the feather barbules being widely separated. Unlike ostriches, these birds are monogamous, but, as in them, incubation is carried on by the male. The young birds are striped.

Cassowaries (*Casuarius*) (fig. 128) are restricted to North

Fig. 128.—Cassowary (*Casuarius*)

Australia, Ceram, New Guinea, and adjacent islands. Their appearance is very striking, and in some respects they are the most modified of all the running birds. The head and upper part of the neck are bare and brilliantly coloured—blue, red, green, or yellow, according to the species. In some cases there are fleshy outgrowths or wattles on the neck. The beak is not unlike that of an ordinary fowl in shape, and there is a peculiar "casque" on the top of the head, formed by an outgrowth from the skull. The shining plumage is bluish-black, and resembles hair in texture rather than feathers. The small wing bears four or five quills, represented, however, only by their shafts. Feathers

extend down to the ankle-joints of the legs, which are characterized by the further feature that the innermost toe bears a claw twice as long as those on the other toes.

Unlike the other ostrich-like birds, they inhabit forest-regions. The nesting habits, so far as known, resemble those of the emeu.

The *Kiwis* (*Apteryx*) (fig. 129) are New Zealand birds of remarkable appearance, and much smaller than the preceding forms, being about the size of a hen. The reduction of wings and tail is greater than in the other running birds, and their plumage is more hair-like, peculiarities which confer a certain grotesque resemblance to a man with his hands in his pockets. Two marked characters at once distinguish them from the ostrich-like forms of the same group. One is the slender snipe-like beak at the end of which the nostrils are situated. The other is found in the presence of the first toe. The legs are very strong, and all four toes are provided with powerful claws. At the base of the beak are a number of long whisker-like feathers. Kiwis are nocturnal birds, and resemble the emeu and cassowary in their nesting habits The cream-coloured eggs are of relatively enormous size, being about 5 inches in length.

Fig 129 —Kiwi (*Apteryx*)

CHAPTER IV

STRUCTURE AND CLASSIFICATION OF REPTILES

The two great groups of Backboned Animals so far considered, *i.e.* Mammals and Birds, are both characterized as "warm-blooded", for the animals included possess hot blood which is maintained at a practically constant temperature independently of external conditions. This peculiarity is associated of necessity with very perfect breathing arrangements (see pp. 45 and 147), and results in great activity and high intelligence.

Contrasted with these two high groups we have the Reptiles and still lower forms, which are "cold-blooded", in the sense that the blood is of the same approximate temperature as the surrounding medium—air or water, as the case may be—and is therefore hot in hot weather and cold in cold weather. Such animals, as compared with Mammals or Birds, are in the main sluggish, and not remarkable for intelligence.

Reptiles are a very ancient group, and probably form the stock from which both Mammals and Birds have been derived, on which subject more will be said in another section of the book. Reptiles preceded Mammals as the dominant Vertebrates both on sea and land, and many remarkable groups once existed which are now entirely extinct. Recent Reptiles include crocodiles, lizards, turtles, and snakes, with their respective allies. The most average forms are probably *Lizards*, of which there are three British species, and a brief description of the most typical of these will be an appropriate introduction to the study of Reptiles in general.

The Sand Lizard (*Lacerta agilis*) is commonly to be found on sunny slopes in this country, and appears to be especially abundant where the soil is of a sandy nature. When thoroughly warmed by basking, it is capable of moving with considerable rapidity, hence the specific name *agilis*. Average specimens are not more than 5 or 6 inches long, but this length is sometimes exceeded by 2 or 3 inches.

External Characters.—The flattened triangular head, with blunt forwardly-directed apex, is separated by a short ill-marked neck from the long rounded trunk, and this again passes into a very long slender tail. The shape is well adapted to the darting movements by which the animal makes its way through heather and grass. The limbs are short and primitive-looking: they are divided into the same regions which we have found to be typical for Mammals (p. 24) and Birds (p. 140); *i.e.* upper arm, fore-arm, and hand for the front-limb, corresponding to the thigh, lower leg, and foot in the hind-limb. There are five fingers and five toes, all ending in claws, and the shortest digits in their respective limbs are the thumb and great toe. The body is not lifted well off the ground by the limbs, and this is not because these are short, but owing to their "sprawling" arrangement, knee and elbow projecting outward, instead of being brought well below the trunk, as in a dog, cat, or other Mammal.

Returning to the head, the flatness of which as compared with a Bird is due to the relatively small brain, we note a large mouth extending far back from the front end of the snout, near the tip of which can be seen the two small nostrils. Further back come the good-sized eyes, which, as in a Bird, are provided with a nictitating membrane (p. 140), as well as with upper and lower eyelids. Some little distance behind either eye, not far from the angle of the mouth, is an auditory aperture, devoid, as in Birds, of an external flap or pinna. Here, however, the external passage of the ear (external auditory meatus), which leads down to the tympanic membrane, is excessively short, so that the membrane is brought close to the surface, and can readily be seen without dissection.

The only other aperture of importance is that of the cloaca (p. 146), a transverse cleft on the under side of the trunk where it passes into the tail.

While Mammals are distinguished by the possession of hair, and Birds by their feathers, Reptiles have an exoskeleton of scales, which, like hairs and feathers, are products of the outer layer of the skin, or epidermis. Bony plates, or bony scutes formed in the deeper part of the skin (dermis), may be present as well. The scales of the Sand Lizard are very obvious structures with a definite arrangement. Those on the head are comparatively large, and it has been found convenient to give some

of them special names, as their arrangement is constant for a given species, and is therefore an important aid to classification. The scales on the upper side of the trunk are small, but those on its under side are much larger, and arranged in longitudinal rows, while those of the tail are also of a good size, and arranged in regular encircling rings.

The colour of the Lizard harmonizes with its surroundings, and this "general resemblance" is both "protective" and "aggressive", as it renders the animal inconspicuous as well to its own foes as to the insects upon which it preys. The ground colour of the male is greenish on the upper side, shading into lighter colour below; but in the female duller tints of grey or brown predominate. Both sexes are darkly marked on the upper side, there being an especially well-marked stripe running down the middle of the trunk.

Endoskeleton (fig. 130).—The same regions are present as in a bird, but though there are many points of agreement there are numerous differences, partly due to the great peculiarity of the bird. The lizard's bones do not contain the air-cavities which are so often found in birds.

In the *skull* the brain-case is much smaller in proportion than in a bird, a fact directly related to the relative size of the brain in the two animals. With few exceptions the bones of the skull are the same as in the bird, but the boundaries between them remain fairly distinct in the adult, instead of fusing together so as to obliterate all boundaries. There is one occipital condyle (see p. 28), or rounded prominence for union with the backbone, each half of the lower jaw is made up of several pieces, and the presence of a movable quadrate bone enables the mouth to be opened very widely (see p. 143): all points of agreement with Birds and difference from Mammals. An interesting peculiarity is found in the presence of a small hole, the *parietal foramen*, in the top of the brain-case. Imbedded in the floor of the mouth, and giving attachment to the muscles of the extremely mobile tongue, is the gristly "hyoid apparatus", made up of a central pointed portion, from which three slender rods run out on each side.

The *backbone* consists of a large number of vertebræ, and is fairly flexible throughout, exhibiting neither of the extremes which characterize the Pigeon (see p. 144). The usual regions can be made out, except that it is not possible to say where the thoracic

vertebræ end and the lumbar ones begin, and the numbers are as follows:—Cervical, 8; thoracic and lumbar together, 22; sacral, 2; caudal, very numerous, but of no constant number. The ends of the centra or bodies of the vertebræ are neither flat as in Mammals nor saddle-shaped as in Birds, but concave in front and convex behind, or, technically speaking, *procœlous*. This is the commonest arrangement among recent reptiles. The first two joints of the neck are constituted by atlas and axis as in a Mammal (see p. 26) or Bird; but the odontoid peg which projects forwards from the front end of the latter is never fused with, though firmly fixed to, it. The peg is in reality a bit of the atlas centrum which has been appropriated by the axis for the purpose of making a pivot. There are two interesting peculiarities about the tail, one of which consists in the presence of small **Y**-shaped bones united to the under sides of many of the caudal vertebræ, the stem of the **Y** being directed downwards. In this way a canal is formed in which the great blood-vessels of the tail are sheltered, an arrangement which is found in various groups of backboned animals. Another and more interesting peculiarity is found in the fact that the body of almost every vertebra in this region remains unossified, *i.e.* is not of bony nature, across a narrow central strip. The tail of a lizard is extremely brittle, partly as a result of the arrangement described, and this would appear to be a defensive provision, whereby, supposing the animal to have been attacked in the rear by an enemy, a part is sacrificed to save the rest.

Slender curved *ribs* are attached from the fourth neck-vertebra right back to the sacrum, and, as elsewhere, the first thoracic vertebra is taken to be the one bearing the first rib that is connected with the sternum. Only five pairs are so connected in the Sand Lizard, the means of union being slender gristly *sternal ribs*, by which the bony *vertebral ribs* are continued in the downward direction (see p. 29). Each of the two sacral vertebræ possesses a strong transverse process on each side, by which attachment to the hip-girdle is effected, and it has been shown that these processes ossify or become bone independently of the bodies of these vertebræ, fusing with them subsequently. On this account the processes are looked upon as ribs which have united with the vertebræ to which they belong—a phenomenon which is paralleled elsewhere.

The *sternum* is an insignificant lozenge-shaped piece of cartilage, running back behind into a couple of slender rods, with which the hinder sternal ribs are united, while the others connect with the two posterior sides of the lozenge.

Skeleton of Limbs.—This is in many ways interesting, being to a large extent of what is called "generalized type", an expression which deserves a little examination, as it embodies an important idea constantly recurring in biological works. It often happens that in examining a series of human contrivances designed to meet the same or a similar end, a kind of general plan or similarity will be found to run through all of them. Under such circumstances it would very likely be possible to pick out some one of the series which might be looked upon as embodying the ideas involved in a general kind of way, and from which, by modification, the other members of the series might be derived. This case would form a *generalized type* of the entire series. A good instance is that of various kinds of habitation, of which the moderate-sized houses which make up a formal row may be taken as generalized types. In such a house would probably be found, among other apartments, breakfast-room, dining-room, drawing-room, study, and a certain number of bedrooms, all these, let us suppose, of reasonable size, and square or rectangular shape. Modifications of such an average plan might be effected in one or more of the following ways:—(1) Variation in *shape*: the dining-room, for example, might be oval or polygonal. (2) Variation in relative *size*: the drawing-room, say, might be the same size as the dining room, or smaller, or it might be larger. (3) Variation in *number*, either on the side of increase, as by addition of a second drawing-room, or on the side of decrease, as by reducing the number of bedrooms. In the latter case a particular sort of room, perhaps the study, might be made so small as to deserve the name of a "vestige", and the next step would be its complete suppression. (4) Coalescence, or fusion of rooms, as, for instance, by complete or partial removal of the party-wall separating two adjoining rooms. By application of these principles of alteration, a small cottage on the one hand, or a castle on the other, might be referred to the same type as the average house, and it is obvious that dwellings of all styles and sizes are, after all, neither more nor less than houses or places of human habitation, and must fulfil certain average requirements. It may also be noted, in passing, that the house

illustration may be made to illustrate very well another biological principle, *i.e.* "change of function", already alluded to in the Introduction (p. 13). A room intended for a particular purpose may be, of course, used for some other purpose, as when what should be a study is converted into a nursery. An amusing case is known to the writer of a small tradesman, who, on retiring, thought of taking a house of more ambitious nature than the one that had been connected with his shop. Seeing a bath-room for the first time, he remarked that he had no use for it, and would make it a lumber-room.

Some meaning will now be attached to the expression "generalized type" as applied to the limbs of a lizard. But we may go a step further, and speak of a "theoretical type", by which is meant an arrangement so generalized that it is rarely, if ever, found in existing animals. The endoskeleton of the limbs of terrestrial vertebrates is best understood by reference to such theoretical types, which may here be conveniently explained.

As has already been pointed out (see pp. 29 and 145), the skeleton of either fore- or hind-limb consists of a girdle by which attachment to the trunk is brought about, and the skeleton of the free limb, and it has also been indicated (p. 24) that there is a correspondence or *serial homology* between fore- and hind-limb.

Girdles.—The theoretical type of *shoulder-girdle* consists of a dorsal piece, *scapula*, and two ventral pieces, the larger, *coracoid*, behind, and the smaller, *precoracoid*, in front. At the junction of the scapula with the other elements is a shallow *glenoid cavity*, to which the bone of the upper arm is attached. The *hip-girdle* consists similarly of three pieces—a dorsal *ilium*, uniting below with a ventral and anterior *pubis*, and a ventral and posterior ischium. Corresponding in position to the glenoid cavity is a somewhat deeper cup, the *acetabulum*, for the attachment of the thigh-bone.

Free Limb.—If the limb of a lizard be spread out at right angles to the body, in what is usually called the *primitive position*, and a line or axis drawn down its centre, an anterior or *preaxial* edge can be distinguished from a posterior or *post-axial* edge, and an upper or *dorsal surface* from an under or *ventral surface*. Taking first the fore-limb, we find an upper-arm bone or *humerus*, down the centre of which the axis runs, and succeeding this in the fore-arm, two bones, a preaxial *radius*, a post-axial *ulna*. Next

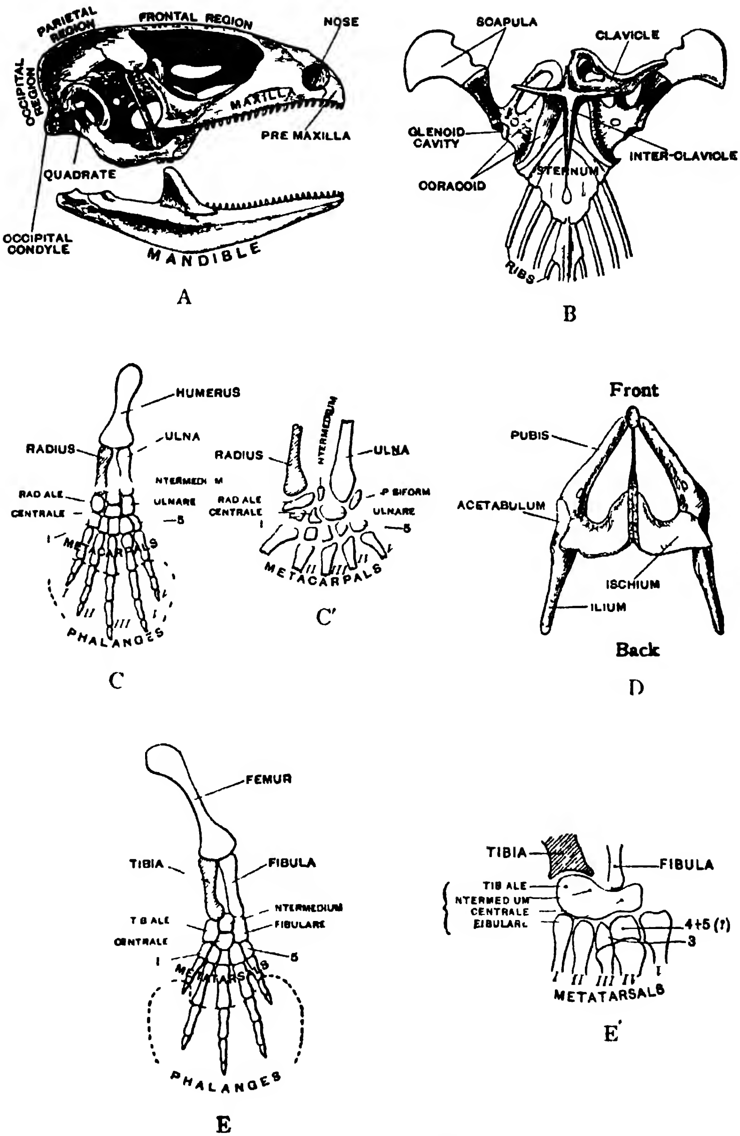


Fig 130 —Skeleton of Lizard

A, Skull B Sternum and Shoulder Girdles C Pattern Fore Limb 1 and 5 first and fifth carpalia. C, Wrist of Lizard D, Hip Girdles. E, Pattern Hind Limb 1 first tarsale 4+5 fourth and (?) fifth tarsalia. E', Ankle of Lizard.

comes the wrist (*carpus*), made up of a number of small elements, arranged in a near or proximal and a far or distal row. The proximal row consists of three elements—a preaxial *radiale*, so called because it is on the radial side, an *intermedium* in the middle, and an *ulnare* on the side of the ulna. The distal row of carpal elements consists of five *carpalia* for the support of the five fingers, and called, beginning on the preaxial side, carpale 1, carpale 2, &c. Wedged in between the two rows of carpal elements is a *centrale*, named from its central position. The five carpalia support the five fingers, each of which has a *metacarpal* at its base, followed by slender *phalanges*, two of these going to the thumb or first digit, and three to each of the others.

The free part of the *hind-limb* is supported by elements which correspond preciselv with those of the fore-limb, as in the following table:—

Fore-Limb.	*Hind-Limb.*
1. Upper-arm bone (humerus).	1. Thigh-bone (femur).
2. Bones of fore-arm:	2. Bones of lower leg:
(*a*) Preaxial radius	(*a*) Preaxial tibia.
(*b*) Postaxial ulna.	(*b*) Postaxial fibula.
3. Wrist (carpus):	3. Ankle (tarsus):
(*a*) Radiale, intermedium, ulnare	(*a*) Tibiale, intermedium, fibulare.
(*b*) Centrale.	(*b*) Centrale.
(*c*) Carpalia: 1, 2, 3, 4, 5.	(*c*) Tarsalia: 1, 2, 3, 4, 5.
4. Metacarpus.	4. Metatarsus:
Metacarpalia: 1, 2, 3, 4, 5.	Metatarsalia: 1, 2, 3, 4, 5.
5. Phalanges:	5. Phalanges:
Thumb, 2; other digits, 3 each.	Great toe, 2; other digits, 3 each.

If we compare the skeleton of the lizard's limbs with the theoretical arrangement just described, the result will be as follows:—

Fore-Limb—Shoulder-Girdle.—The dorsal scapular section is represented by two parts—an upper *supra-scapula* and a lower *scapula* proper, while on the ventral side both *coracoid* and *pre-coracoid* of the theoretical type are seen. But over and above this we find additional parts in the form of a slender *collar-bone* (clavicle) situated in front, and running towards the middle line to join its fellow, besides which there is a cross-shaped *inter-clavicle*, belonging to neither girdle, but coming between them, and also attached to the sternum. *Free Limb.*—Here there is a very close correspondence with the theoretical type, differences being chiefly seen in the presence of an accessory bone in the carpus coming

just outside the ulnare, and the presence of an extra phalanx in the third digit, and two extra phalanges in the fourth digit. The extra carpal bone is known as a *pisiform*, and is of different nature from the rest, for it has been developed in the course of a tendon (see p. 48), the muscle belonging to which acquires thereby a greater leverage.

Hind-Limb -Hip-Girdle.—Except in unimportant particulars we get a very close agreement with the theoretical type, all three elements—*ilium*, *pubis*, and *ischium* being present. *Free Limb.*—There is considerable departure from the simple type as regards the tarsus, the proximal part of which is represented by one element, probably representing tibiale, intermedium, fibulare, and centrale, all fused together. Only two distal elements can be seen in the tarsus; one of these is probably tarsale 3, for the third digit is united with it, while, since digits 4 and 5 both unite with the other distal elements, it perhaps may be regarded as equivalent to the two corresponding tarsalia fused together. It is not clear what has become of the first and second tarsalia. The digits are supported by the same number of phalanges as in the hand. One point is specially worthy of remark, *i.e.* the ankle-joint comes in the *middle* of the tarsus, not, as in Mammals, between the tarsus and bones of the lower leg. Such a mesotarsal ankle-joint is characteristic of both Reptiles and Birds (see p. 146).

Digestive Organs (fig. 131).—Lizards feed on insects, small worms, and the like, and possess numerous small conical teeth, and a very mobile forked tongue. The teeth are not lodged in sockets as in a Mammal, but are fixed on to the inner sides of the bones which form the margin of the upper and lower jaws. There are also two small groups of teeth on the palate. It is particularly worthy of notice that reptilian teeth, as compared with those of ordinary Mammals, are not only extremely numerous, but not divided into different kinds—incisors, canines, &c. And while a Mammal develops two sets of teeth, a Reptile has, as a rule, an indefinite succession of them, a worn-out tooth being replaced by a new one, which grows up at its base. The tongue can be protruded to some distance, and is worked by a well-developed set of muscles attached to the hyoid apparatus, the large size of which is thus accounted for.

The *digestive tube* or *gut* into which the mouth-cavity is continued consists of a *gullet*, wide slightly curved *stomach*, fairly long

coiled *small intestine*, and short wide *large intestine*, terminating in a *cloaca*. A large *liver*, provided with a *gall-bladder*, and a small *pancreas*, open into the beginning of the small intestine.

Circulatory Organs (fig. 131).—As in Mammals and Birds, we can distinguish between blood system and lymph system, of which only the former need here be considered.

Blood System.—This is a closed system of tubes, consisting of heart, arteries, veins, and capillaries, in which the cold blood circulates. Seen under the microscope, a drop of lizard's *blood*

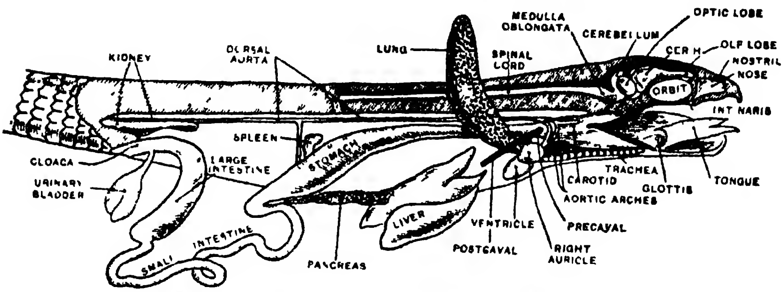


Fig 131 —General Structure of Lizard CER H, cerebral hemisphere

presents much the same appearance as a drop of bird's blood, and is made up of a clear liquid plasma, in which float irregular white corpuscles capable of executing creeping movements, and oval red corpuscles, each of which is a nucleated cell.

The *heart* is enclosed in a double-walled pericardial sac, and is distinctly a more imperfect organ than in the Mammal or Bird, as, though there are two auricles, there is only one ventricle, and therefore the impure blood received by the right auricle from the body mixes to some extent with the pure blood received from the lungs by the left auricle. As will be seen, however, there are several devices by means of which the mixture of the two sorts is partly prevented.

The three great *caval veins*, two in front and one behind, bring back the impure blood to the heart, as in a Mammal or Bird (see fig. 102), but, instead of opening directly into the right auricle, they pour their blood into a thin-walled pouch, the *venous sinus*, which communicates by a valvular opening with the right auricle. As usual, the purified blood from the lungs is poured by pulmonary veins into the left auricle. The two auricles squeeze their blood through a single valvular opening into the thick-walled ventricle,

but the two kinds of blood do not mix here, for the party-wall between the auricles projects into the opening, and divides it into a right half and a left half. Although the cavity of the ventricle is single, there is a well-marked ridge protruding into it which must be regarded as an incipient partition, and actually divides the ventricle when it contracts into a right half, mostly receiving impure blood, and a left half, mainly containing pure blood. Impure blood is pumped to the lungs through a *pulmonary artery* arising from the right half of the ventricle, just as the same artery is given off from the right ventricle in a Mammal or Bird (see p. 40 and fig. 102).

A notable peculiarity here deserves mention. In a Mammal (see p. 41) the great body-artery, known as the *aorta*, starts from the left ventricle in an *aortic arch*, which curves round to the left, while in a Bird there is a similar arrangement, except that the aortic arch curves round to the right. In the Lizard there is, as it were, a combination of both conditions. There is a *right aortic arch*, resembling a Bird's in that it arises from the left half of the ventricle and curves over to the right. Since this arch starts from that side of the ventricle which receives pure blood from the left auricle, it has blood of that sort pumped into it. And since the arteries supplying the head and fore-limbs are branches of the right aortic arch, these parts of the body are necessarily supplied with pure blood. And it is natural that the brain above all organs should get a pure blood supply, which it does in this way.

But there is also a *left aortic arch*, curving as in the Mammal, and conducting away some of the impure blood from the right half of the ventricle. The *dorsal aorta* is formed by the union of right and left arches, receiving pure blood from one, and impure blood from the other, and therefore supplying what may be called *mixed* blood to the trunk, tail, hind-limbs, and most of the internal organs. Yet another point deserves attention. Each of the aortic arches is *double* for part of its extent, and really represents a pair of arches fused together. The presence of one or more arches at the beginning of the great arteries of the body in terrestrial Vertebrates strikes one as peculiar, and without reference to Fishes is inexplicable. As will later be explained, however, it is an indication of descent from gill-bearing ancestors (see p. 244), for the circulatory organs of lung-bearing forms are not

constructed on a brand-new pattern especially suited to their requirements, but are simply a modification of the more ancient arrangement found in fish-like animals. In both Mammals and Birds the modification is very perfect, and there is a complete separation of pure and impure blood; but in Reptiles and Amphibia the separation is less complete, and the relative sluggishness of these creatures is partly due to the fact that their bodies are to a large extent supplied with mixed blood, *i.e.* with blood which, being a mixture of pure and impure blood, is only imperfectly oxidized.

Not only does the Lizard possess an *hepatic portal system* (see p. 41), by which the blood of the digestive organs is carried to the liver, but there is also a *renal portal system* in connection with the kidneys, by which some of the impure blood from the hinder part of the body is supplied to those organs, the function of which is, as elsewhere, to get rid of nitrogenous waste.

Breathing Organs and Organs of Voice (fig. 131). - The arrangements connected with respiration are here much simpler than in either Mammals or Birds, which is what might be expected, as cold-blooded animals have not the same need for thorough and rapid oxygenation of the blood, though at the same time it must be remarked that Lizards exhibit less complication than is usual among Reptiles.

On the floor of the mouth behind the tongue there is a slit-like *glottis* leading into the organ of voice or *larynx* that forms the beginning of the *wind-pipe*, which runs back and forks into two bronchi, one for each lung (see p. 46). These air-tubes are supported by gristly rings, and thus prevented from collapsing. Nothing is present equivalent to the syrinx or song-box of a Bird (see p. 149). The *lungs* are spindle-shaped bags, the linings of which are raised into a honey-combing of ridges, by which the surface exposed to the air is considerably increased.

Nervous System and Sense Organs (fig. 131).--Only a few points call for special attention. As previously remarked (p. 192), the flatness of the head is an indication of the relatively small size of the *brain*. At the front end of this organ are the club-shaped *olfactory lobes*, which supply the fairly well developed organs of smell, and pass back into the smooth *cerebral hemispheres*, the relatively small size of which as compared with a Bird (see p. 149) is an index of inferior intelligence. Still farther back are two

large *optic lobes*, much like those of a Bird (see p. 150), but placed side by side on the upper side of the brain instead of being separated from one another. Lastly comes the ***medulla oblongata***, which passes gradually back into the *spinal cord*, and exhibits on its upper side, just behind the optic lobes, a small smooth lobe which corresponds to the complicated *cerebellum* found in a Mammal or Bird (see pp. 52 and 150). A side view of the brain shows clearly a sharp downward bend (cranial flexure) in the region of the medulla oblongata.

The same *sense organs* are present as in a bird, though there are many differences in detail; and it may be particularly mentioned that the complex bag or membranous labyrinth (see p. 150), which is imbedded in the side wall of the skull and constitutes the inner ear, is rather less complex.

In dealing with the skull it was mentioned that there is a small hole, the parietal foramen, in the roof of the brain-case. This hole is occupied by a rounded structure, which in some Lizards has clearly the structure of an eye, so much so that it is usually called the *pineal eye*. It is connected with a sort of stalk which runs upwards from that part of the brain-axis of which the cerebral hemispheres are outgrowths. Even in Lizards this unpaired eye is more or less degenerate, and it is only represented in most of the Vertebrates by the stalk just mentioned, to which the name of "pineal body" is usually given. Even in the human brain a pineal body can be distinguished, and the fact that the philosopher Descartes regarded it as the seat of the soul has invested it with a certain curious interest. It is clearly to be regarded as one of those "vestigial organs" or "vestiges" which are of common occurrence in the animal body, and represent the dwindling remains of structures which were of importance in ancestral forms.

Development.—The Sand-Lizard lays eggs much like those of a bird, but with softer shells.

Classification of Reptiles. — Leaving the numerous extinct groups out of consideration, as these will be dealt with elsewhere, Reptiles may be divided into five orders, as follows:—

1. Crocodilia: Crocodiles, Alligators, &c.
2. Chelonia: Turtles and Tortoises.
3. Lacertilia: Lizards.
4. Ophidia: Snakes.
5. Rhynchocephala: Hatteria, a lizard-like New Zealand form.

It may be well at this point to summarize the chief features, all of which have been illustrated in the foregoing description of a Lizard, in which these five groups agree, or, in other words, to give a definition of the Reptilia.

Reptiles are cold-blooded Vertebrates defended by an exo-skeleton composed of either epidermic scales, or bony dermal scutes, or it may be of both. In those forms which possess well-developed extremities, there are always more than three digits in the fore-limb, and commonly five in the hind. *The skull is jointed on to the backbone by a single occipital condyle, each half of the lower jaw consists of several bones*, and the surfaces of the vertebral centra are not saddle-shaped. The sacrum is made up of two vertebræ. The interclavicle, when present, does not fuse with surrounding parts, and in existing forms the ilia do not extend far in front of the acetabula, both pubes and ischia unite together ventrally, and the tarsus fuses neither with the tibia nor with the metatarsus. *The ankle-joint is in the middle of the tarsus.* Conical teeth are usually present (except in Chelonia) and *the gut ends in a cloaca.* The heart possesses two auricles but (except in Crocodilia) only one ventricle, and in all cases the body is partly supplied with mixed blood. There is never less than one pair of aortic arches. The brain is small, and the optic lobes are placed close together on its upper side. *Breathing is in no case effected by means of gills.*

There are many points of agreement between Reptiles and Birds, and this is especially striking if extinct forms are taken into consideration. Those characters which are printed in *italics* in the above definition are common to both groups, which are often associated together into a larger division, the Sauropsida, contrasting with Mammals on the one hand and Ichthyopsida (Amphibia plus Fishes) on the other.

Order I.—Crocodiles (Crocodilia)

Crocodiles and Alligators (fig. 133) much resemble gigantic lizards in appearance, and agree with these in many particulars of structure, though decidedly of higher type. As is well known, these animals spend a large part of their time in water, and some of their peculiarities of structure are related to the aquatic habit. The large and hideous head provided with formidable

jaws is separated by an ill-marked neck from a long body, and this again passes into a long and powerful tail, which is the chief swimming organ. The body is flattened from above downwards, and the tail, in correspondence with its function, from side to side. The sprawling lizard-like limbs do not lift the trunk well off the ground, the feet are webbed to some extent, and there are five digits in the fore- but only four in the hind-limb, the little toe being represented only by a small bone visible in the prepared skeleton.

Returning to the head, we find several arrangements that are of special use to an aquatic form. The slit-like nostrils are situated on the tip of the snout, and can be closed by muscular action so as to prevent entry of water when the animal is submerged, while their position enables breathing to go on when only a very small part of the body is above the surface. As in birds and lizards (as well as some mammals), the eye possesses not only upper and lower eyelids but also a third eyelid which can be drawn over it for protection, and the tympanic membrane, corresponding in position to that of the lizard (see p. 192), is provided with a little protective flap or "ear-lid" which can be folded over it.

The chief peculiarity of the *skin* (fig. 133) is found in the fact that it develops a very complete exoskeleton, composed externally of rectangular horny scales, which on the tail and upper and lower sides of the trunk are disposed in regular longitudinal and transverse rows. Some of these scales project upwards from the upper side of the tail, forming a jagged crest. This, however, is not all. Underlying the scales of the upper and sometimes of the under surface are sculptured bony plates (scutes), which are developed in the deeper part of the skin (dermis). The arrangement of the scales and scutes differs in different species, and affords characters which are of use in classification. The strong musky odour which distinguishes crocodiles is due to the secretion of musk-glands, some of which open on the edge of the upper jaw, others into the cloaca, and the remainder on the dorsal surface of the trunk.

The ***endoskeleton*** of the crocodile can be compared point for point with that of the lizard, though it presents a number of interesting peculiarities. In the large and massive ***skull*** the boundaries between the separate bones can be always

made out, and the upper surface is sculptured something like the scutes. It is, indeed, almost certain that some of the flat bones which help to cover in the skull in those vertebrates possessing a bony skeleton are in reality scutes which have sunk inwards and attached themselves firmly to underlying parts.

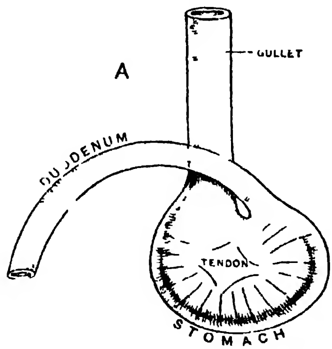
The bones of the jaw are very long, and their margins present a large number of sockets, arranged in a single row, for the reception of the formidable pointed teeth. As in a bird or lizard, the lower jaw hinges on behind to an elongated bone known as the quadrate (see p. 143); but whereas in those forms the bone in question is more or less movable so that a sort of double jaw-joint is constituted, here it is firmly fixed to the skull. Such a double joint detracts somewhat from firmness, which is very necessary to an animal that, like a crocodile, has to overcome prey possessing considerable muscular strength. And further, the long jaws enable the mouth to be opened widely enough without the presence of a joint of the kind. A notable peculiarity is found in the very great length of the bony palate which supports the roof of the mouth, and above which runs a passage into which the cavities of the nose open, and along which air is conducted to and from the glottis, or aperture of the windpipe. In a bird or lizard the internal openings of the nasal cavities are situated on the roof of the mouth fairly far forwards, but in the crocodile the arrangement described throws them very far back, and as the top of the windpipe projects into them a distinct air-passage from the external nostrils backwards is constituted, so that breathing can take place when the tip of the snout is above water, even if the mouth be open, without any danger of water getting down into the lungs. Similar anti-choking arrangements are found in other air-breathing aquatic vertebrates, and will be described in another chapter.

The thoracic *ribs* exhibit one feature which is characteristic of birds, each of them having a backwardly-directed plate on its margin not very far from the backbone (see p. 145). These uncinate processes add to the firmness of the wall of the chest. Not only are ordinary ribs present, but also "abdominal ribs", situated behind the sternum and developed in connection with the muscles. It is interesting to note that ribs of the kind are also present in the oldest known fossil bird (*Archæopteryx*),

which also approached reptiles in other more important particulars, such as the possession of teeth and a long jointed tail.

In the skeleton of the *limbs* the absence of clavicles may be noted (see p. 145), and also the fact that both tarsus and carpus are considerably modified. One of the bones of the former (calcaneum) has a heel-like projection, and this is the only case outside the Mammalia where anything of the kind is present.

The *digestive organs* (fig. 132) are interesting in a number of ways. The strong conical teeth which form an irregular row along the margin of each jaw are, as already mentioned, imbedded in distinct sockets, and, as in lizards, are replaced to an indefinite extent by successors which grow up from below and push them out as they get worn down with wear. When the jaws are



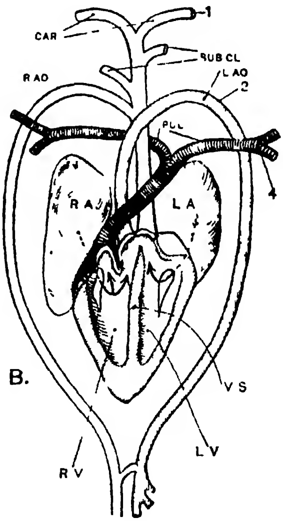


Fig. 132. Structure of Crocodile.

A, Stomach and related parts. B, Diagram of Heart and great blood vessels. R A and L A, right and left auricles. R V and L V, right and left ventricles cut open. V S, ventricular septum. 1, 2, 4, aortic arches of left side. R AO, Right aorta. L AO, Left aorta. SUB CL, subclavian arteries. CAR, carotid arteries. PUL, Pulmonary arteries. Arrows show course of blood.

brought together the upper and lower teeth interlock, forming a very efficient arrangement for seizing and holding. There are no teeth on the roof of the mouth as in a lizard (see p. 199), and the tongue is a flat rounded organ devoid of any great mobility. Crocodiles are in the habit of pulling their prey under water and holding it there till drowned, during which operation a good deal of water must get into the mouth of the aggressor. In the way already explained this water is prevented from

getting down into the lungs, and there are soft projections at the back of the mouth-cavity which can be brought together so as to keep it out of the gullet. In other words, the hinder part of the mouth cavity is partitioned into a *pharynx* (see p. 34), which passes back into the wide *gullet*. This in its turn communicates with a *stomach* which is singularly bird like, since part of it is modified into a muscular gizzard (see p. 146). The resemblance is strengthened by the crocodile's habit of swallowing stones, which presumably help, as in a bird, to grind up the food. This is the more necessary since the teeth are not suited for chewing, and the prey is either swallowed whole or in large pieces, according to its size. As in Birds and Lizards (see pp. 146 and 200) the *large intestine* terminates in a *cloaca*, which opens to the exterior by a longitudinally oval aperture situated on the under side of the root of the tail.

The *blood, heart*, and *blood vessels* (fig. 132) are much like the corresponding parts in the lizard (see p. 200), the most important difference being that there are two ventricles, a feature possessed by no other known reptile. This limits the impure blood to the right side of the heart and the pure blood to the left, as in mammals and birds, but the advantage gained is less than at first sight appears, for the two kinds of blood mix *outside* the heart. This is so because we still have, as in the Lizard (see p. 201), two aortic arches, a right which takes origin in the left ventricle and carries off pure blood from it, and a left which conducts away impure blood from the right ventricle. It is clear, therefore, that the dorsal aorta, which is formed by the union of the two arches and which supplies the body behind the fore-limbs, must contain mixed blood, and the two arches also communicate by a small hole just where they leave the heart. A reduction of the aortic arches has taken place as compared with the Sand Lizard (see p. 191), for each of them is here single instead of being formed by the partial union of two. If the left arch were entirely done away with we should have a condition closely resembling that found in the bird (see fig. 102), and all parts of the body would be supplied by pure blood. There can be little doubt that some of the remote reptile-like ancestors of birds possessed circulatory organs much like those of the crocodile, and that in them part of the body was consequently supplied with mixed blood.

The *breathing organs* and parts connected with them differ from those of the lizard not only in the arrangement of the air-passages as already described, but also in the structure of the lungs themselves, which have relatively thick spongy walls. A similar arrangement, however, is found in some large lizards, and, speaking generally, it is only small reptiles which have very simple lungs. Crocodiles also possess an imperfectly-developed representative of the muscular partition known as midriff or diaphragm, which plays such an important part in the breathing movements of Mammals (see p. 46).

The *brain* of a crocodile is of higher type than a lizard's, both cerebral hemispheres and cerebellum being much larger in proportion. The *sense organs* are also more complex, especially those connected with smell and hearing. In the latter case it is interesting to note that the complex bag known as the membranous labyrinth (fig. 103), which constitutes the essential part of the inner ear, is shaped very much as in a bird, there being a well-developed curved tube to represent the coiled cochlea of Mammals.

Crocodiles are hatched out from eggs much resembling those of birds, and laid in holes or imperfect nests scooped out in the sand, where they get the benefit of the sun's heat. The young reptile has a horny wart on the tip of its snout, which helps it to break through the firm egg-shell.

The existing members of the order Crocodilia (fig. 133) are found in tropical and sub-tropical regions both in the New and Old Worlds. Three groups are commonly recognized:—(1) Alligators; (2) Crocodiles proper; and (3) Garials.

Alligators, with the exception of a Chinese species, are confined to the tropical parts of America. The snout is relatively short and broad, and the different teeth are of very unequal size, among the large ones being the first and fourth in the lower jaw, which bite into pits in the upper jaw in such a way that they are hidden from view when the mouth is shut. There are several special features in the skull, of which perhaps the most striking is the shortness of the region where the two halves of the lower jaw unite together in front. Some members of the Alligator group possess scutes on the under side of the body as well as on the upper. The hind-limbs have a rounded outline and the toes are only half-webbed.

Three species are known of the Alligator proper, one being found in China, and the others in the south-east part of North America, of which two by far the best known is the Pike-headed or Mississippi Alligator (*Alligator Mississippiensis*), which may attain the length of about 15 feet. The first name given to this creature expresses a resemblance to the fresh-water fish well known as the Pike.

The remaining members of the Alligator group, the *Caimans* or *Jacares*, are limited to Central America and the tropical parts of South America. The different species vary greatly in size; all but one, however, being much smaller than the Mississippi Alligator. Unlike the Alligators proper the Caimans possess ventral scutes, and those which make up the dorsal armour are firmly united with one another.

Crocodiles proper have a very wide distribution throughout the tropics, being found in America, Africa, South Asia, and North Australia. The head is somewhat narrower and longer than in alligators, and the teeth are not so markedly unequal. Although, as before, the large first lower tooth bites into a pit, this is not the case with the large fourth lower tooth, which merely bites into a groove and is partly visible when the mouth is shut. The united part of the lower jaw is rather longer than in alligators, as might be expected from the shape of the head, and there is no ventral bony armour as in caimans. The hind-limbs have a jagged posterior fringe, and the feet are more completely webbed than in alligators.

Probably the most familiar species is the Nile Crocodile (*Crocodilus Niloticus*), which was regarded as sacred by the ancient Egyptians, and like other animals which figured in their religion was considered worthy of embalmment. It has now been exterminated in the lower Nile, where it was formerly very abundant, and its range includes South Africa, Senegal, Madagascar, and Syria. Large specimens may considerably exceed the Mississippi Alligator in size.

The Indian Crocodile (*Crocodilus palustris*) ranges from Baluchistan to the Malay region, and avoids the tidal parts of rivers. Another Indian species, the Estuarine Crocodile (*C. porosus*), has exactly the contrary habit, as the name indicates, and is not only common in estuaries, but swims out to sea for a considerable distance. This fact is interesting, for the vast

Fig. 133.—Crocodilia

1. Chinese Alligator (*Alligator Sinensis*). 2 Spectacled Caiman (*Caiman sclerops*). 3 Nile Crocodile (*Crocodilus Niloticus*). 4. Ganges Garial (*Garialis Gangetica*).

majority of existing reptiles are confined to land or fresh water, though some of the extinct groups were exclusively marine. The Estuarine Crocodile is one of the fiercest and most dreaded species, and at the same time probably the largest, for a specimen has been recorded as having the great length of 33 feet. It ranges from the east of India to South China, North Australia, and the Solomon and Fiji Islands.

American Crocodiles have slender snouts, a feature possessed in an exaggerated form by a West African Crocodile (*C. cataphractus*).

Garials form a small group of crocodilian reptiles, distinguished by extremely slender snouts, and jaws armed with a large number of comparatively small teeth, all fairly equal in size and arranged with greater regularity than in the other forms. These special modifications convert the jaws into a very perfect fish-catching arrangement, which is paralleled in some of the aquatic Mammals (Cetacea). The first and fourth lower teeth bite into grooves above, and, as is but natural, the united part of the lower jaw is extremely long. The feet are more completely webbed than in other crocodilians, and both fore- and hind-limbs have a posterior ragged fringe. There are only two existing genera, both confined to the south of Asia.

Schlegel's Garial (*Rhynchosuchus Schlegeli*) is found in Borneo, and may attain the length of 14 feet. The better-known Gangetic Garial (*Garialis Gangetica*) is confined to the Ganges, Indus, Brahmaputra, and some smaller Indian rivers. It is of larger size than the Bornean Garial (20 feet), and the snout is longer and more slender. By the natives they are regarded as sacred.

Order 2.—Toothless Reptiles (Chelonia)

This order includes the Turtles and Tortoises, toothless Reptiles provided with a remarkable defensive exoskeleton.

The most familiar member of the group is the small Grecian Tortoise (*Testudo Græca*), common as a pet in this country, and indigenous to the south of Europe (fig. 134). The short broad trunk is enclosed in a strongly arched shell, forming a sort of box with an opening in front into which the head, neck, and fore-limbs can be withdrawn, and a similar opening behind for the benefit of the hind-limbs and stumpy tail. The head is

rounded, and the toothless jaws, covered as in birds with firm horny sheaths, give it a very characteristic appearance. Two small rounded nostrils are seen close together on the front of the head, the fairly large eyes are provided, as in lizards, with three eyelids, and behind each of them is a depression in which the tympanic membrane is visible. Protection is afforded by a number of horny plates united by their edges. The immobility of the trunk is largely made up for by a fairly long and exceedingly

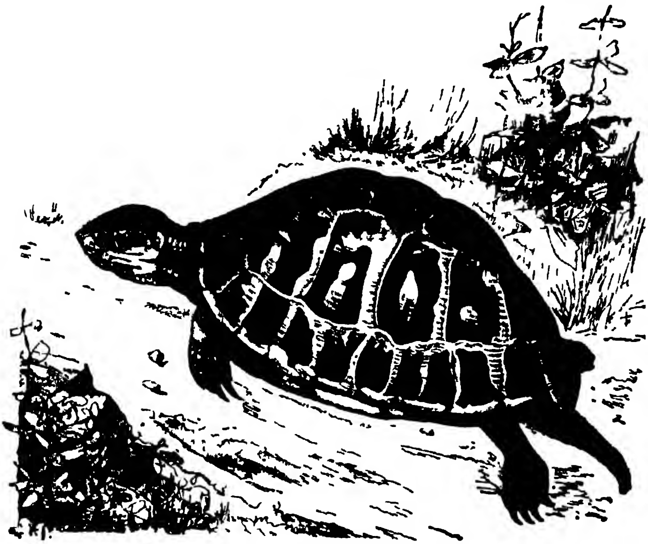


Fig. 134.—Grecian Tortoise (*Testudo Græca*)

flexible neck, covered by soft skin. When retracted it is thrown into an S-shaped curve. The stumpy limbs are adapted for terrestrial locomotion, and can lift the body well off the ground. As, however, the movements are extremely slow, defensive armour is a necessity, and on the slightest alarm the animal withdraws head, neck, tail, and limbs into the cover of the shell, when the protective arrangements are completed by the horny plates on the head and strong overlapping scales which are present on the limbs.

The usual limb-regions are present, though not well marked externally, and the existence of five digits in either extremity is indicated by a corresponding number of blunt claws.

The *exoskeleton* resembles that of caimans, in that there are

not only horny plates and scales of epidermal nature, but also bony pieces developed in the deeper part of the skin both above and below. Here, however, these pieces cannot be stripped off with the skin, but are to a great extent intimately welded to parts of the internal skeleton. The arched upper or dorsal half of the shell is termed the *carapace*, and the flat under or ventral piece with which it is firmly united at the edges is the *plastron*. It will be convenient first to deal with the superficial horny shields and then with the underlying bony plates. Beginning with the carapace, there is a series of *neural shields* running down the centre, and these are flanked on either side by broad transverse *costals*, outside which again are more numerous *marginals*, forming a right and left series separated in the extreme front by a median *neck-shield* (nuchal) and behind by a pair of *caudals*. Some of the marginals on either side bend sharply round to the under surface and help to cover the bones of the plastron. The greater part of this, however, is veneered by six pairs of horny shields, of which those in front (gulars) and behind (anals) are smaller than the rest, which have received the names of humerals, pectorals, abdominals, and femorals.

When these horny shields are stripped off, a number of bony plates are exposed which have a very similar arrangement, though their number is not the same, and therefore, of course, their edges do not correspond with those of the overlying plates, as is the case with the armour of caimans. Running down the middle of the carapace are eight *neural plates*, which may be regarded as the flattened tops of vertebræ, and which are continuous on each side with a similar number of *costal plates* fused with the underlying ribs. The carapace is completed by a *nuchal plate* in the middle of its front margin and *pygal plates* similarly placed behind, while a series of eleven *marginal plates* are disposed on either side. The plastron is made up of one unpaired plate, and four others arranged in pairs. The former is possibly to be compared with the interclavicle of a lizard (see p. 198), while the others are in all probability to be regarded as equivalent to the abdominal ribs of the crocodile.

As will have been gathered from the foregoing description, there is intimate union between bony plates belonging to the external skeleton and parts of the *internal skeleton, i.e.* the

ribs and trunk vertebræ, and we see here that the girdles of the limbs are brought within the shelter of the ribs, a remarkable and unique arrangement. The immobility of the trunk is largely made up for by the great flexibility of the neck, which is supported by eight vertebræ, of which the centra exhibit great variety in the shape of their ends. There is no breast-bone, the presence of the plastron rendering it quite unnecessary.

As regards the *skull*, it need only be noted here that the jaws possess a continuous sharp bony edge for the support of the horny sheaths which do duty as teeth. The lower jaw is jointed on to a massive quadrate bone which, as in a crocodile, is firmly fused with the rest of the skull.

The skeleton of the *fore-limb* corresponds pretty closely to the theoretical type, except that some of the bones have fused, as radiale with centrale, and carpale four with carpale five. In the *hind-limb* there is a fair correspondence with the type, but, as in Reptiles generally, there is a good deal of fusion in the ankle-bones and a tendency for the ankle-joint to come between the two rows of these.

The *food* of the Grecian Tortoise consists mainly of vegetable matter, but it also devours sundry small animals, such as worms, insects, and snails. The *digestive organs* present no points of very special interest, but it may be noted that the tongue is comparatively immobile, as in the crocodile, and, as in that animal, the large intestine ends in a cloaca which opens externally by a longitudinal slit.

Except as regards its flattened shape, the *heart* of a tortoise closely resembles that of the Sand Lizard (p. 191), and there is also agreement in reference to the great blood-vessels which enter and leave it, each of the two aortic arches, however, as in crocodiles and the larger lizards, being single instead of double for a part of its course The body is therefore, as in other Reptiles, largely nourished by imperfectly-purified blood, and a tortoise is a particularly good example of the sluggishness and cold-blooded condition entailed by this arrangement. It also exhibits in a very marked way the great tenacity of life which distinguishes cold-blooded vertebrates when compared with birds and mammals.

The *breathing-organs* agree in most respects with those of

the crocodile, but the internal nostrils open on the roof of the mouth, as the habits of the animal do not require any special provision to be made for a distinct breathing tract as distinct from the cavity of the mouth. It may also be remarked that the immobility of the trunk presents a certain obstacle to the rapid renewal of the air in the lungs, and this is probably the chief reason for the sluggishness of chelonians.

The *brain* presents the usual parts, and is, for a reptile, of comparatively high type, being only inferior to that of the crocodile.

Tortoises are developed from hard-shelled eggs much like those of a bird. About a dozen of these are deposited together in a hole scooped out in the earth, and are afterwards carefully covered up. A warm spot is selected for the purpose, and the eggs, which are laid in early summer, are hatched out by the heat of the sun.

The following groups are recognized among the Chelonia, and in dealing with them space will only permit of allusion to some of the more interesting forms:—

(1) Leathery Turtles.
(2) S-necked Chelonia.
  (*a*) Land and Fresh-water Tortoises.
  (*b*) Turtles.
(3) Side-necked Tortoises.
(4) Soft Tortoises.

(1) *Leathery Turtles.* — This group contains but a single species, the Leathery Turtle or Luth (*Sphargis* or *Dermatochelys coriacea*) (fig. 135), which differs in many important particulars from other Chelonia, not only from the terrestrial and fresh-water forms, but also from the Turtles proper, which, like it, are marine. It is the only living representative of an important extinct group, some members of which attained a very considerable size, and is the largest existing marine species, being when full-grown over 6 feet long. The limbs are modified into large nailless flippers, which are very efficient swimming organs. These, however, are not its special peculiarity, for similarly modified limbs are found in ordinary turtles, but this is found in the nature of the "shell". The carapace is made up of numerous bony pieces united together in a tesselated manner and quite free from the

underlying ribs and vertebræ, besides which there is a complete absence of overlying horny plates, the place of these being taken by leathery skin raised into a small number of prominent longitudinal ridges. The plastron is not so well developed as in

Fig. 135 – Leathery Turtle (*Dermatochelys coriacea*)

ordinary turtles, and is covered by ridged skin resembling that on the upper surface. These creatures are found in the tropical parts of all the great oceans.

(2) The *S-necked Chelonia* include the large majority of existing species, and are so called because the head, when retracted, is drawn straight back into the shell, being at the time thrown into an S-shaped curve.

(*a*) *Land and Fresh-water Tortoises.*—The genus *Testudo* (figs. 134 and 136), to which the Grecian Tortoise (*Testudo Græca*) belongs, is a representative of the largest family of Land Tortoises, or indeed of Chelonia generally, including a score of genera which embrace between them some 113 species. The family is found in all parts of the world except Australia, New Guinea, and the related islands. Among the most interesting

forms included in the same genus with the Grecian Tortoise are fourteen giant species, which either are or have been within the last 300 years inhabitants of some of the islands in the Indian and South Pacific Oceans. Of these probably the best known are those found in the Galapagos Islands off the north-east coast of South America. Several species have been described, one of which (*Testudo nigrita*) was described by Darwin as reaching such large dimensions that large specimens could only be lifted by from six to eight men.

The European Pond-Tortoise (*Emys orbicularis*) may be mentioned as a good example of a fresh-water form. In accordance with its aquatic habits, the shell is much flatter than in a land tortoise, and the feet are webbed. It is a native of South Europe, South-west Asia, and parts of North Africa. Specimens, mostly of small size, are often exhibited for sale in this country.

(*b*) *Turtles* are marine Chelonia obviously adapted for aquatic life, as may be seen from their flattened shells and paddle-like limbs, the digits of which have for the most part lost their claws. The front end of the carapace is notched, and the head can be only partly retracted. The true turtles somewhat resemble the Leathery Turtles (see p. 217) in form, a result of adaptation to the same sort of life, but, unlike the latter, the shell is covered by horny plates, and some of the digits have retained their claws. There are also important differences as regards the plastron and carapace. The former, though not so complete as in the Grecian Tortoise, is more so than in the Leathery Turtle, while the carapace is made up of the same elements as in the tortoise and is firmly connected with the internal skeleton. Two species may be noted here—the Green Turtle and the Hawk's-bill Turtle.

The Green Turtle (*Chelone midas*), found in all the warmer parts of the ocean, is the species which has attained a doubtful sort of fame in connection with aldermanic feasts. Its short beak devoid of a hook is well adapted for biting off the pieces of sea-weed which constitute the food. The horny plates which cover the carapace are united by their edges.

The Hawk's-bill Turtle (*Chelone imbricata*) has the same wide distribution as the preceding species, but is somewhat smaller. Its strongly-hooked beak accords with a carnivorous

habit, and the overlapping horny plates covering the carapace are the source of "tortoise-shell".

(3) The *Side-necked Tortoises* are a rather remarkable assemblage of fresh-water form, owing their name to the fact that

Fig. 136.—Tortoise (*Testudo sulcata*) and Green Turtle (*Chelone mydas*)

the head and neck cannot be drawn straight back into the hollow of the shell, but the same end is effected by bending back the head sideways. These tortoises are all restricted to the southern land-masses, and range right round the globe, being represented in South America, Africa, Madagascar, Australia, and New Guinea.

(4) *Soft Tortoises.*—These are found in the rivers of the

hotter parts of Asia, Africa, and North America, their name being derived from the fact that the shell is entirely devoid of any horny plates. Not only so, but the carapace is deficient as regards bony elements, the marginals being either absent or largely so, and it is not united to the plastron, which is still more deficient. The shape of the body and limbs accords with the thoroughly aquatic habit, but the latter are not so completely

Fig. 117.—Nilotic Soft Tortoise (*Trionyx triunguis*)

converted into flippers as in the turtles. The head is provided with a curious tapering snout, and is situated upon a very long mobile neck, which on the one hand can be retracted as in the S-necked forms, and on the other can be shot out with extreme rapidity. This is, no doubt, a useful acquisition to the large carnivorous members of the group, but is at the same time a very unpleasant one, for these large species are very fierce, and the natives are often badly bitten by them. The skin is of a greenish colour as a rule, with yellow spots.

Of the six genera included among the Soft Tortoises, *Trionyx* is by far the most important and also the most widely distributed,

being the only one which extends into the New World as well as the Old. Typical species are the Gangetic Soft Tortoise (*Trionyx Gangeticus*), the Nilotic Soft Tortoise (*T. triunguis*) (fig. 137), which feeds largely on the eggs and young of the crocodile, and the common American Soft Tortoise (*T. ferox*), a native of the North American streams which flow into the Gulf of Mexico, and noted as a destroyer of the alligator's eggs and young.

Fig. 138.—Wall Gecko (*Tarentola Mauritanica*)

Order 3.—Lizards (Lacertilia)

The large Lizard order, of which a fair average sample has already been described at some length, embraces representatives in all parts of the globe except the polar regions, and includes no less than twenty families, containing about 1700 species. It will only be possible here to mention a few of the more interesting forms, included in the families of—1. Geckos; 2. Scale-footed Lizards; 3. Agamoids; 4. Iguanas; 5. Snake Lizards; 6. Venomous Lizards; 7. Monitors; 8. Common Lizards; 9. Skinks; and 10. Chameleons.

1. *Geckos* are small nocturnal lizards, with large eyes, and lobed feet adapted for climbing. They are found in all the warmer parts of the earth, and the Wall Gecko (*Tarentola Mauritanica*) (fig. 138) of the Mediterranean shores is the most familiar example. One structural feature of the family deserves notice here, *i.e.* the shape of the centra of the vertebræ. These are biconcave, a very primitive feature specially

characteristic of fish and low types of other vertebrate groups. In Reptiles generally it is most commonly the case that the centra are concave in front but convex behind.

2. *Scale-footed Lizards* make up a small family of snake-like forms found in Australia, Tasmania, and New Guinea. The fore-limbs are entirely wanting, though the hind-limbs are represented by lobe like projections, but for which these creatures might well be mistaken for serpents. An examination of their structure, however, clearly shows that they are true lizards.

The Common Scale-foot (*Pygopus lepidopus*) of Australia and Tasmania may be mentioned as an example.

3. The family of *Agamoid Lizards* is a very large one, limited to the southern and eastern parts of the Old World. A typical form is the Black-lipped Tree-Lizard (*Calotes nigrilabris*) of Ceylon. Its body is of a metallic green tint, except the lips and sides of the head, which are black. Among the more remarkable members of the family are the so-called *Flying Lizards* or *Dragons* of South Asia, small forms which certainly do not live up to the latter name. These animals do not fly in the proper sense of the word, but there is a parachute-like expansion on each side of the body, supported by extensions of some of the ribs, and capable of being folded up or extended. The Malayan species (*Draco volans*) is well known. The *Thorny-tailed Lizards* of Africa and Asia have the tail covered with rings of spiny scales, and one species, the Dabb (*Uromastix spinipes*), is common in Arabia, Egypt, and Crete. Australia furnishes two remarkable species in the Frilled Lizard (*Chlamydosaurus Kingi*), which has the habit of walking about on its hind-legs, and the Moloch (*Moloch horridus*), covered with large thorny spines.

4. The *Iguanas* are, with few exceptions, found in the warmer parts of America and the West Indies. The Common Iguana (*Iguana tuberculata*) is a good type of the family, and the prominent toothed ridge running down the middle of the back is a characteristic feature. It is a vegetarian and lives mostly in trees, but is also a very active swimmer. It may attain a length of over 4 feet, which includes, however, the exceedingly long tail. One of the most interesting members of the family is the Galapagos Sea-Lizard (*Amblyrhynchus cristatus*), the only known marine member of its order. In size it rather exceeds the

Common Iguana, which it resembles in the presence of a dorsal-toothed ridge. The head, however, is smaller and rounder, and there is a group of conical scales on the upper surface, while the powerful tail is flattened from side to side and thus rendered an efficient swimming organ, there being also an indication of webbing between the digits. The food consists of sea-weeds. Among the most bizarre species related to the Iguanas are the Helmeted Basilisk (*Basiliscus Americanus*) of Central America and Costa Rica, which perhaps suggested one of the fabulous animals of mediæval zoologists, the somewhat similar Capuchin Lizard (*Corythophanes cristatus*) of Costa Rica, and the Californian Horned "Toad" (*Phrynosoma cornutum*), the general appearance of which certainly does suggest a spiny sort of toad, possessed, however, of a tail.

5 The *Snake-Lizards*, of which the name suggests the external appearance, have their head-quarters in Central America and the West Indies, but also occur north and south of this in the New World, and are represented in Europe, North Africa, and India They not only possess horny scales but also underlying bony scutes, which on the top of the head attain a relatively large size.

The most familiar species is the Blind-Worm or Slow-Worm (*Anguis fragilis*), common in Britain, and having a wide range in Europe, occurring also in North Africa and in Asia. It is

Fig 139 – The Scheltopusik *Ophisaurus apus*, a blind worm native to S Europe and S W Asia

often mistaken for a snake, and erroneously regarded as exceedingly poisonous. Its popular name dates back to the times when the word "worm" was applied to serpents, and a survival of this old usage appears to remain in some place-names, such as "Worms" Heath, in Surrey. The Blind-Worm exhibits no

external trace of limbs, though vestiges of these are present in some of its relatives (see fig. 139), and its teeth are slender and fang-like. Its food consists of slugs, worms, insects, and the like. The specific name "fragilis" has reference to the readiness with which the tail breaks off when the animal is handled or struck, a protective arrangement not uncommon among lizards (p. 194).

6. *Venomous Lizards* are represented only by one genus containing two species, both North American, one being from Mexico (*Heloderma horrida*) and the other from Arizona (*H. suspecta*). They are carnivorous forms of considerable size, coloured and mottled in such a way as to make them conspicuous objects when seen apart from their natural surroundings. The poison arrangement is something like that found in snakes, there being slender fang-like teeth grooved to conduct a poisonous fluid from glands at their bases.

7. *Monitors* are the largest living lizards, and are distributed over the warmer parts of the Old World. In general proportions

Fig. 140. The Nile Monitor (*Varanus Niloticus*).

they are not unlike the typical form previously described, with which also they agree in the possession of a well-developed forked tongue capable of being thrust far out of the mouth. A common species is the Nile Monitor (*Varanus Niloticus*), which

ranges over most of Africa (fig. 140) The food consists of small vertebrates and various kinds of eggs, including those of the crocodile. The name Monitor embodies an erroneous idea that this creature hisses in a peculiar way when a crocodile approaches, and so gives a "warning" of its presence.

8. What may perhaps be called the *Common Lizards* (Lacertidæ) include some 100 species, distributed over Europe, Africa, and Asia. The Sand Lizard (*Lacerta agilis*) of Britain is one example, and the only other British member of the order (except the Blind-Worm), the Common Lizard (*Zootoca vivipara*), is another. Among the larger and handsomer forms may be noted the Green Lizard (*Lacerta viridis*), ranging from Portugal to Persia, and found abundantly as far north as Germany, and the Wall Lizard (*Lacerta muralis*), which is specially characteristic of the countries bordering the Mediterranean.

9. The *Skinks*, or *Burrowing Lizards*, constitute a family of which the distribution is world-wide. The Common Skink (*Scincus officinalis*), found on both sides of the Red Sea and on the north side of the Sahara, suggests in appearance a fish mounted on legs. The shape and smoothness of the scales are apparently features related to the burrowing habit, and the animal also possesses the useful power of seeing with its eyes shut, for the lower eyelid is provided with a transparent area which answers the purpose of a window.

Fig 141 —Snake-eyed Lizard (*Ablepharus pannonicus*)

The European Snake-eyed Lizard (*Ablepharus pannonicus*) (fig. 141) of South-east Europe and parts of South-west Asia is a slender creature with very small five-toed limbs.

The Three-toed Bronze Lizard (*Chalcides tridactylus*) of Italy, Sicily, Sardinia, and the opposite part of Africa, is snake-like in form, with small reduced limbs. From Roman times to the present day it has been groundlessly regarded as extremely venomous.

The most extraordinary member of the family, however, is the Stump-tailed Lizard (*Trachysaurus rugosus*) (fig. 142) of Australia, with short flattened tail, strong limbs provided with well-developed claws, and very prominent regularly-arranged scales.

10. *Chameleons* are small tree-inhabiting reptiles, familiarly known as possessing the power of changing the colour of their skins to harmonize with the surroundings for the time being.

Fig. 142. Stump-tailed Lizard (*Trachysaurus rugosus*)

They exhibit many remarkable peculiarities of structure related to climbing and the capture of their prey, which consists of insects. They form a well-marked group, differing so much from the other subdivisions of lizards that it would probably be better to consider them as a distinct order. The scales are very small and granular, and the remarkable head is possessed of enormous eyes which can be moved independently of one another, while each is provided with a circular eyelid, in the middle of which is a small round hole. There is no external trace of organs of hearing. Both limbs and tail are modified for climbing. The tongue is club-ended and worm like, and can be rapidly protruded to a distance equalling the length of the body (exclusive of the tail). Being rendered sticky by a special secretion, it forms a very efficient insect-catching apparatus. The lungs of Chameleons are of interesting structure, there being an approach to the air-sacs of Birds (see p. 148), for each lung, though fairly spongy and thick-walled in front, is produced behind into a number of thin-walled slender processes which extend between the various internal organs. It does not appear, however, that

these outgrowths are of much use in breathing, but they can be distended with air so as to swell out the body. This may be a protective arrangement

Nearly fifty species of Chameleon are known, of which the vast majority are natives of Africa and Madagascar, though

Fig 143 Common Chameleon (*Chamæleo vulgaris*)

outlying members of the group are found in Arabia India and Ceylon while one species the Common Chameleon (*Chamæleo vulgaris*) (fig 143), ranges round the eastern and southern shores of the Mediterranean, and also extends into the south of Spain

Order 4—Snakes (Ophidia)

Although at first sight there seems to be a great deal of difference between snakes and lizards, careful examination shows that there are important points of resemblance, and some zoologists include the two groups in a single order *Squamata*, among the distinctive features of which are the possession of well-marked overlapping scales, a transverse cloacal opening, quadrate bone movably attached to the skull so as to give a double jaw-joint, and simple lungs.

The elongated cylindrical form is well suited for gliding through thick undergrowth or herbage, and it may be for climbing, while some snakes are modified for swimming and others for burrowing. The resemblance to the limbless lizards is striking, but here as elsewhere too much importance must not be attached to similarity of shape, as this may result from the same or similar habits in animals which are not closely related. No snake ever possesses the least trace of fore-limbs, even their girdles being entirely absent, as also is the sternum. Snake-like lizards, on the other hand, may have very small fore-limbs or external traces of the same; and if not, as in the blind-worm, dissection shows that the girdles are represented, nor is the sternum ever absent. As regards hind-limbs, these are generally entirely absent in snakes, but vestiges are in some cases to be found one on each side of the cloacal aperture.

The head is small and flattened, passing without any perceptible neck into the trunk, and that again into a gradually-tapering tail. In nearly all cases the mouth is a wide slit, and a small rounded nostril can be seen on each side of the snout at or near its tip. The stony stare which is so characteristic of a snake is due to a very peculiar arrangement. Instead of upper and lower eyelids, there is a circular area of transparent skin by which the eye is protected, and occupying the space between this and the front of the eyeball is a tear-chamber always full of the secretion of the tear-gland.

Numerous overlapping *scales* cover the body, these being replaced on the head and under surface of the body by horny plates. *Ventral shields*, as those in the latter position are termed, are never to be seen in the limbless lizards. Snakes exhibit a great variety of colouring and marking, by which protection or other purposes are served, as will be seen elsewhere. One very characteristic habit, not peculiar to this group, however, is the periodical shedding of the outer part of the skin. The snake wriggles out of this slough, turning it inside out in the process.

The internal organs of snakes (fig. 144) exhibit a number of peculiarities, dependent partly on the elongated shape of the body, partly on the way in which prey is secured and swallowed, and partly on the manner of locomotion. The first factor, for example, influences the number of the vertebræ, and

the way in which the internal organs are packed into the long but narrow space available for the purpose.

The *skull* is made up of very hard and polished bones, its most notable features being the loose union between the various bones connected with the jaws. The two halves of the lower jaw, for instance, are not firmly united at their tip, as is the case of most reptiles, but are only connected by an elastic ligament which permits of a good deal of stretching. Not only so, but the upper jaw also is capable of a good deal of movement. This flexibility has to do with the necessity for great expansion in the act of swallowing large prey, and also plays a large part in enabling poisonous forms to use their poison-fangs effectively. It may also be noticed that the hyoid apparatus is extremely small. The long *backbone* is made up of some two or three hundred vertebræ, the centra of which have the usual reptilian shape, *i.e.* concave in front and convex behind. Such a large number of ball-and-socket joints give a very large amount of flexibility, but some provision is necessary to impose a limit to this, as otherwise dislocation would be liable to occur when complicated curvings were being described. This is partly provided for by overlapping articular processes on the arches of the vertebræ, as in most Vertebrates with well-ossified backbones (see p. 26), but in addition to these a pair of wedge-shaped projections stick out from the front of each arch and fit into corresponding pits at the back of the preceding one. It should be mentioned that similar processes are found in some other reptiles, as, for example, Iguanas, where, however, they are not so well developed.

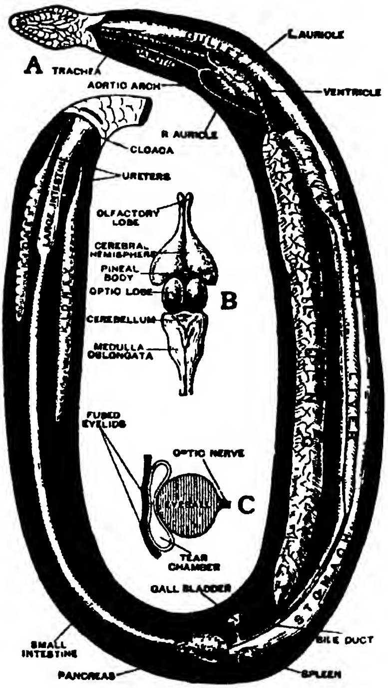


Fig 144 —Structure of a Snake
A, General dissection B, Upper side of brain C, Diagrammatic vertical section to show tear-chamber in front of eye

In the absence of both sternum and pelvis, means of distinguishing between regions of the backbone largely fail, and though the first two vertebræ are undoubtedly cervical, it is best to speak of the rest as divided into two kinds only—trunk vertebræ and tail vertebræ. Each of the former kind bears a pair of simple curved *ribs*, the free ends of which are firmly connected to a pair of the ventral epidermal shields.

The most interesting features connected with the *digestive organs* have reference to the tongue and teeth. The former is slender and forked, and can be drawn back into a kind of sheath. It is not a sting as is popularly believed, but probably serves as an organ of touch, and may perhaps also play a part in the "fascination" which a snake seems to exert over its victims. The backwardly-curved, sharply-pointed teeth are in most snakes arranged along the margins of the jaws and in two rows along the palate. In poisonous forms the two front teeth in the upper jaw are grooved or channelled for conducting poison from special glands, and it is these "poison fangs" which are capable of inflicting fatal wounds. Such a snake, therefore, is deadly in virtue of its power of giving a poisoned bite. The "sting" of a scorpion or wasp is an entirely different thing, and the organ which administers it is situated at the hinder end of the body, as most of us have practical cause to know in the case of the latter animal.

There is no occasion to dwell upon the *circulatory organs*, for in essential respects these are constructed on the plan described for the Sand Lizard (see p. 191).

The *breathing organs* are distinguished by one or two remarkable peculiarities. In the first place, the top of the windpipe is drawn out into a tube, the end of which protrudes from the mouth when prey is being swallowed, an operation that would otherwise stop the breathing altogether. The two lungs are very unequally developed, for whereas the left one is reduced to a mere vestige, the other is correspondingly large and extends far back in the body, the arrangement being convenient in a body so elongated and narrow. The hinder part of this right lung is thin-walled, and appears to chiefly serve as a reservoir of air.

The *brain* agrees in the main with the type described for the Sand Lizard, and in regard to *sense organs* one peculiarity

F. g 145 Pyt ons and B as

1 I d an P thon *Python molurus* 2 West African Python *P s b* 3 Anac 1 *E* … 4 Boa Constrictor *B* …

has already been dealt with, *i.e.* the tear-chamber of the eye. The organs of hearing consist solely of the membranous labyrinth, the sound-conducting middle ear being entirely absent. The tongue appears to be used as an organ of touch.

As at least a thousand species of snakes are known, it will only be possible here to mention a few of the more important forms. The following groups can be recognized:—1. Simple-toothed Snakes; 2. Whip-Snakes; 3. Cobras and Coral Snakes; 4. Sea-Snakes; 5. Vipers; and 6. Blind-Snakes.

1. *Simple-toothed Snakes* are non-poisonous forms, in which both upper and lower jaws are provided with rows of solid, hook-like teeth. Here are included the giant snakes known as *Pythons* and *Boas* (fig. 145), which are found in the tropical regions all round the world, but are especially abundant in South America. Among the species may be mentioned the Indian Python (*Python molurus*), which may attain a length of 30 feet, the somewhat longer West African Python (*P. sebæ*), the Anaconda (*Euneces murinus*) of tropical South America, which is credited with being the largest of living snakes, and the much smaller Boa Constrictor (*Boa constrictor*) from the same region. All these forms kill their prey by crushing, and it may also be noted that their skins are very beautifully marked with elaborate patterns. They are the only snakes which possess externally visible remains of the hind-limbs.

Not very distantly related to the giant snakes are the two harmless forms (fig. 146) which are found in Britain, *i.e.* the Grass Snake (*Tropidonotus natrix*) and the Smooth Snake (*Coronella lævis*). The former is commonly met with in the neighbourhood of fresh water, and it is a good swimmer. The frog is the favourite article of diet, but small mammals, birds, and fish are also eaten. This snake can readily be distinguished from the poisonous Adder by its colour and markings. The darker upper surface is usually brownish or greenish, marked by darker spots or narrow transverse bands, while at the back of the head is a good-sized yellow or orange patch on each side, behind these again being a broad dark "collar". The under-side of the body is mottled, and of much lighter hue.

The Smooth Snake is not common in Britain, but is sometimes found in dry places in the southern English counties. It is smaller than the Grass Snake, and may readily be distinguished

by the markings on its upper side, consisting of a dark blotch on the neck and a double series of brown spots running down the body It feeds on other reptiles

Both these British species especially the Grass Snake, have a wide distribution outside of Great Britain

Fig 146

1 Grass Snake (*Tropidonotus natrix*) 2 Smooth Snake (*Coronella la*- 3 Adder (*Pelias berus*)

2 *Whip Snakes* and their allie are green tree inhabiting forms, native to the tropical regions of Asia, Africa, and America The head is small and pointed, the body extremely slender But the most remarkable peculiarity is seen in a varying number of the hinder teeth of the upper jaw, each of which has a groove in frort. Such grooves on the upper teeth of serpents generally

serve the purpose of conducting poison from a poison-gland into wounds made by the teeth, and it has been asserted that this is the case in some members of this group.

3. *Cobras* and *Coral-Snakes* are tropical forms in which the front upper teeth are grooved poison-fangs, conducting venom from poison-glands. Cobras are found in South Asia and Africa. Examples are the Common Cobra of India (*Naia tripudians*), called "cobra de capello" (hooded snake) by the Portuguese settlers on account of its power, characteristic of the genus, of inflating the skin of the neck when irritated.

The Coral-Snake (*Elaps corallinus*) of South America and the West Indies is a small form, in which the body is beautifully marked by broad scarlet rings alternating with much narrower black rings with greenish edges.

4. *Sea-Snakes* are venomous forms ranging from the Persian Gulf eastwards as far as New Guinea and North Australia. Their poison-fangs are of the same kind as described for cobras, &c., and the hinder part of the body is flattened from side to side so as to constitute a powerful swimming organ. Unlike land snakes they cast their skins in pieces, and not in a continuous slough

5. *Vipers* of all snakes are the most specialized as regards the mechanism of the poison-fangs. Of these, two are present, and they are the only teeth in the upper jaw. The groove seen on the front of the fangs of other poisonous forms is here converted into a canal, open above to receive the fluid from the large poison-gland, and below so that this may be introduced into the wound. Hook-like teeth of the ordinary solid kind are present on the roof of the mouth and along the margin of the lower jaw. The head of a viper is flat and triangular, possessing more than in any other kind of poisonous snake the shape of the conventional "spade" on a playing-card, which is so often quoted as characteristic of venomous species. It is, however, a fallacy to suppose that all the dangerous reptiles of the order can be easily distinguished in this way.

Two species may be taken as examples, the Adder (*Pelias berus*) (fig. 146) and the Common Rattle-Snake (*Crotalus durissimus*). The former is the only poisonous British snake, and it has a very wide distribution in both Europe and Asia. Smaller than the Grass Snake, it may be distinguished from that species not

only by the shape of the head but also by the presence of a dark zigzag stripe running down the back, and it is especially common in dry localities, such as sandy heaths.

The Common Rattle-Snake (fig. 147) is a representative of the "Pit" Vipers, a group characteristic of South Asia and the New World, and so called because they possess a deep pit in front of each eye. This particular kind is a large species

Fig. 147.—Common Rattle-Snake (*Crotalus durissimus*)

(length up to 6 feet) which inhabits North America, and, like five other allied American species, is distinguished by the peculiar organ known as a "rattle". This consists of a number of interlocked horny rings at the tip of the tail, generally supposed to be the remains of successive cast skins, though this is denied by some authorities. The rings are at any rate more numerous in old forms, while to begin with, the rattle is only represented by a button-like knob.

6. *Blind-Snakes* are small animals adapted to a burrowing life, and differing in many ways from other members of the order. The small head merges insensibly into a worm-like trunk, and that again into a very short tail. The body is uniformly covered with rounded scales, the large ventral horny

shields so characteristic of an ordinary snake being absent. The small mouth is on the under side of the head, and cannot be opened widely; nor is this necessary, as the food consists of ants and other small creatures. Strong horny plates protect the front of the head, and each of the vestigial eyes is covered by one of these.

Blind Snakes are widely distributed through the hotter parts of both Old and New Worlds, one species, the European Blind-Snake (*Typhlops vermicularis*), ranging from Western Asia into Greece.

Order 5.—TUATARAS (Rhynchocephala)

This order, which is of great age geologically, is of very special interest, because it probably comes near the ancestral stock from which all the groups of Reptiles have sprung and

Fig. 148.—The Tuatara (*Hatteria punctata*)

also, more indirectly, the Birds and Mammals. It is represented at the present day by a solitary species, the lizard like Tuatara (*Hatteria punctata*) (fig. 148), now unfortunately on the verge of extinction, and mainly found on, if not indeed absolutely limited to, some small islands off the north east coast of New Zealand In length it is about 20 inches, and, judging from external characters only, would no doubt be classified with

lizards, as was formerly the practice. The large head is fairly well marked off from the stoutish body, which again passes into a large flattened tail. The short limbs present the usual regions, and each of the extremities possesses five clawed digits. The eyes are large, but there is no external trace of organs of hearing. The scales of the upper surface are in the form of small granules, with the exception of a series of sharp spiny ones which make up a crest running down the middle line. A number of squarish horny plates arranged in transverse rows cover the under surface.

As regards its internal structure the Tuatara differs in many important points from typical lizards, but as the distinctions are largely of a technical nature, only a few of them can be mentioned here.

The *quadrate bone*, to which the lower jaw is hinged, is not movable as in a lizard (see p. 206), but firmly fixed to the skull as in the crocodile, and the two halves of the lower jaw are united together in front only by fibrous tissue. The centra of the *vertebræ* are biconcave in shape (see p. 221), and exhibit other primitive characters. The *ribs* possess uncinate processes as in Birds and Crocodiles (see p. 145), and there are *abdominal ribs* as in the latter (see p. 206). The *teeth* are also peculiarly arranged, there being two rows above, one on the upper jaw and the other on the roof of the mouth, and into the groove between these the teeth of the lower jaw bite, getting in course of time ground to a sharp edge. In the front of the upper jaw are two wedge-shaped teeth, almost reminding one of those present in a rabbit. All these teeth are firmly fused with the edges of the firm bones, and in old animals may be so much ground down that the bones themselves act as biting organs.

CHAPTER V

STRUCTURE AND CLASSIFICATION OF AMPHIBIANS

This class of cold-blooded vertebrates is often confounded with Reptiles, from which, however, its members differ in many important respects, being altogether of simpler type. They are, in fact, more closely related to Fishes, with which they are sometimes associated to form a larger group, the ICHTHYOPSIDA, or Fish-like Animals (Gk. *ichthus*, fish; *opsis*, appearance), as has already been stated. A typical species will here be briefly described, and a comparison with what has been said about the Sand Lizard (p. 191) will illustrate the points of agreement as well as of difference between Amphibians and Reptiles.

The Spotted Salamander (*Salamandra maculosa*) (fig. 152) is a European animal from 6 to 9 inches long which has long attracted attention, mainly perhaps on account of its supposed power of withstanding fire. The flattened rounded head is not separated by any appreciable neck from the somewhat clumsy trunk, which passes gradually back into a long thick tail. The four sprawling limbs are directed a good deal outwards, and scarcely lift the body from the ground: the fore-limb possesses four digits, the hind-limb five. The mouth is a wide slit, and the two small valvular nostrils are placed near the tip of the blunt snout. Large eyes, provided with upper and lower eyelids, are present, but no trace of auditory organs can be seen externally. There is a longitudinal slit, the opening of the cloaca, on the under side of the body near the root of the tail.

The animal is rendered very conspicuous by its colouring, which consists of a ground of black, upon which are arranged broad patches of orange-yellow. The skin differs markedly from that of a reptile, for it is soft, moist, and smooth, being entirely devoid of scales, plates, or claws. Its damp feel is due to the secretion of very numerous skin-glands, some of which secrete

a poisonous fluid. Of these the most conspicuous are grouped so as to form a swelling behind either eye.

The *internal skeleton* (fig. 149) is not so bony as in a reptile, consisting largely of tough membrane and gristle. The *skull*, like that of a mammal, has a pair of condyles at the back for joining on to the backbone. There is no quadrate bone, but the lower jaw is hinged on to a cartilaginous projection of the skull which represents it. The "hyoid apparatus" (see p. 29) in the floor of the mouth consists of a small unpaired cartilage in the middle line and other pieces of cartilage at the sides, of which three pairs are the most conspicuous. These, as we shall see later, are vestiges of structures which were once more important

The *backbone* consists of a considerable number of fairly bony vertebræ, the centra of which are for the most part convex in front and concave behind, just the reverse of what is true for most reptiles. This is only characteristic for some of the Amphibia, however. The following regions can be distinguished: neck, trunk, sacral, and tail. Only the first vertebra, the ring-shaped *atlas*, can be considered as definitely belonging to the neck region. It, and the hinder vertebræ of the tail, bear no *ribs*, which are present, however, as short slender bones in all the others. There is a single sacral vertebra united to the pelvis by means of its ribs, and forming a division between the trunk vertebræ in front and the caudal vertebræ behind. A *sternum* is present in the form of a small plate of cartilage on the under side, but this, from the way in which it is developed, appears to be equivalent to two small abdominal ribs fused together, and is not, therefore, of the same nature as the part so called in the higher vertebrates.

The *limbs* are supported by an internal skeleton, which corresponds very closely with the patterns described on pp. 196–198. Indeed it ought to be stated that these patterns are very largely founded on what is seen in the Amphibia, these being the simplest backboned animals possessing limbs suited for progression on the ground. Two deviations from the pattern may, however, be noted, one being that in the fore-limb the little finger is entirely absent, while the other is that in the pelvic girdle there is no clear boundary between pubis and ischium, the two being represented by a plate of cartilage with the hinder part of which a bony plate is connected.

There are not many points which need detain us in the structure of the *digestive organs* (fig. 150). A considerable number of small *teeth*, with forked crowns, are fused with the bones which form the margins of the jaws, and there are two longitudinal rows of similar teeth on the roof of the mouth. Gullet, stomach, small intestine, and large intestine are present, the last being very short and opening behind into a cloacal chamber. The Salamander is found in damp places, where it lurks in crevices, coming out in the evening or during rain to feed upon worms, snails, and slugs.

Very special interest attaches to the *circulatory organs* (fig. 150), especially as regards the structure of the heart and the arrangement of the large arteries. There is a certain agreement with the Sand Lizard (see p. 191) in so far that the great veins open into a thin-walled *venous sinus*, that pours the impure blood it receives from them into a *right auricle*, which is separated by a party wall from a *left auricle* receiving pure blood from the lungs. Both auricles open into the single *ventricle*. But there is here not even an internally projecting ridge for partial division of the ventricle into right and left halves, and there is an additional region to the heart, the *arterial cone*, a tube which is in communication with the cavity of the ventricle on the right-hand side, and from which the great arteries take origin in the form of four pairs of arterial arches. It is now time to consider more fully the actual meaning of such arches, which have been seen to be present, though in a much less pronounced form, in Reptile, Bird and Mammal (see p. 201).

A Salamander when starting an independent existence is unlike the adult in many important respects, and is therefore called a *larva*. In this particular case, though a pair of small lungs are present, they are to begin with of little or no use for breathing purposes. The efficient organs of respiration are three pairs of feathery gills growing from the sides of the throat, and containing a net-work of delicate blood-vessels. Floating freely in the surrounding water, these gills present a large surface through which the dissolved oxygen can diffuse into the blood and the waste carbon dioxide diffuse out of it. Close inspection reveals the presence of four small *gill-slits* on each side of the throat, by which the back part of the mouth-cavity communicates with the exterior, and each slit is in front of a corresponding

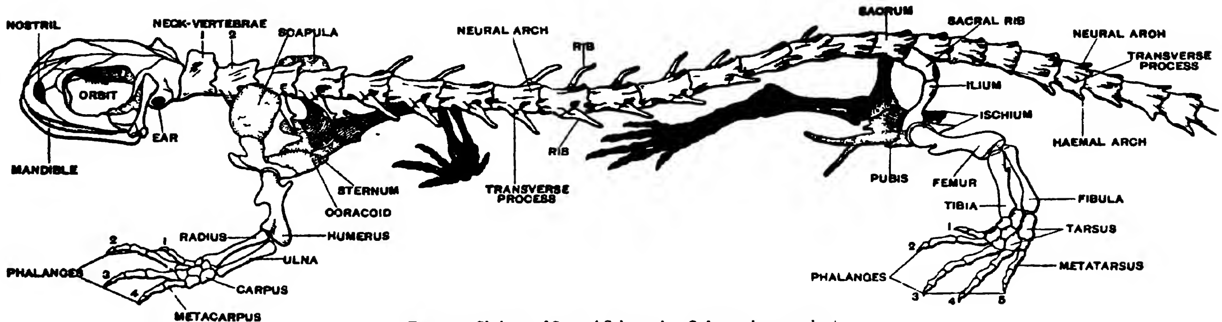


Fig 149 —Skeleton of Spotted Salamander *Salamandra maculosa)*

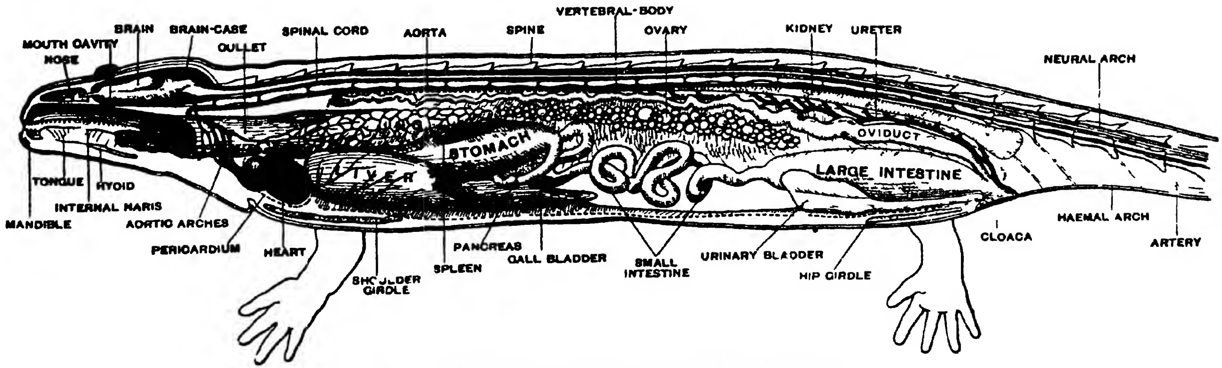


Fig 150.—General Structure of Spotted Salamander *(Salamandra maculosa*

bar-like thickening or *gill-arch.* These bars and slits are good examples of visceral arches and clefts, the presence of which at some period of life or other is one of the primary characteristics of a Vertebrate (see p. 62). The three gills on each side grow out from the tops of the three first gill-arches. The heart of the larva contains impure blood only, returned from all parts of the body, and its function is to pump this blood to the gills for purification through paired afferent branchial vessels which run within the gill-arches. The purified blood is collected up from the gills and distributed to the body by efferent branchial vessels which unite above to form a dorsal aorta. Each afferent vessel, with the corresponding efferent one, constitutes what may be called an *aortic arch.* As the larva gradually assumes the structure of the adult all the gill-slits close, the gills at the same time shrivelling up. Meanwhile the lungs have increased in size, and take on the work of purifying the blood, and the aquatic gill-bearing larva is thus converted into a terrestrial air breathing Salamander. The heart now receives not only impure blood from the body, but also purified blood from the lungs, and it becomes necessary to solve the problem of how to keep these two sorts of blood separate by modifying an arrangement specially adapted for pumping impure blood to the gills. To use an illustration, it is as if a pumping apparatus made for distributing cold water were to be also connected with a warm water supply, and one were then called upon to modify the apparatus so as to keep the two kinds of water as distinct as possible. The problem is only partially solved in the Salamander, for the separation of the two kinds of blood is incomplete, the result being that some of the blood distributed by the heart is impure, some pure, and the rest mixed. Just as if, in modifying the supposed pumping apparatus, we succeeded to a certain extent, part of the warm and cold supplies mixing, however, to give tepid water. In such an event the pump would distribute three kinds of water as regards temperature, *i.e.* cold, warm, and tepid, these corresponding to the impure, pure, and mixed blood of the Salamander.

It would take too much space to fully describe how the circulatory organs of the Salamander are modified during the change from larva to adult, but some of the leading features may be noted. To begin with, the originally single auricle is

divided into two, a right half to receive the impure blood and a left to receive the pure, and although these two halves possess a common opening into the undivided ventricle, yet the prolongation of the party-wall between them into that opening prevents the blood from mixing there. Arrived in the cavity of the ventricle, which is transversely elongated, mixture does not take place so much as would be anticipated, for there is a system of ingrowths from the ventricular wall which largely prevents this, so that the blood passed into the right side of the ventricle remains impure and that on the left pure, while between the two comes a zone of mixed blood. The arterial cone to which blood from the ventricle passes on is placed on the right, and when the ventricle contracts it receives first *impure*, then *mixed* and lastly *pure* blood, as the result of the arrangement just described. Next, as to the way in which the four pairs of aortic arches coming off from the arterial cone are modified for their new purpose. The first pair, which supplied the first gills are converted into *carotid arches* running to the head, the second and third pairs, which supplied the corresponding gills unite to form the *dorsal aorta*, and supply most of the body except the head, while the fourth aortic arches, branches of which have all along supplied the lungs, continue to do so having, however, enlarged. And it is interesting to notice that the parts of the fourth arches which connect them with those in front become converted into fibrous cords through which blood is not able to pass. It is clear therefore that the blood received by the cone must go either to the head, general body, or to the lungs its course for any given moment being in the direction of least resistance. Now, when the ventricle begins to contract, forcing out blood which is quite impure, the easiest course is to the lungs and this impure blood takes that course and flows to the lungs for purification. As that is being accomplished mixed blood begins to flow into the cone, and by this time the easiest course is through the second and third arches to the general body, since the fourth arches have just been filled and can take no more. Meanwhile the ventricle has begun to squeeze out its remaining blood, which is pure, and the easiest course this can take is through the first arches to the head. Containing as it does the brain and highest sense organs, it is important for the head to receive, as in fact it does, the purest blood-supply.

Two things will now have become apparent if the foregoing description has been carefully followed: (1) That the aortic arches found in higher Vertebrates, which always breathe by lungs, point to descent from ancestors which were aquatic and breathed by means of gills growing from gill-arches between which there were gill-slits; (2) the Amphibians and Reptiles are, so to speak, still grappling with the problem of adapting a circulatory system originally suited for pumping impure blood to gills, to the new conditions brought about by the adoption of a terrestrial life. Even in crocodiles, which by development of two ventricles have succeeded in preventing the two sorts of blood from mixing in the heart itself, have not been successful in preventing them from mixing outside the heart (see p. 208). These facts become clearer still when the development of the higher Vertebrates is studied, and in, say, an embryo chick (fig. 151) gill-arches and clefts are clearly to be seen with their aortic arches, although no true traces of actual gills have been discovered. It may also be pointed out that gill-arches are supported by parts of the internal skeleton in the form of jointed rods which unite with unpaired pieces in the floor of the throat, and the "hyoid apparatus", which has been described in various animals, is largely made up of bits of this gill-arch skeleton, now turned to further uses. The cartilages which support the larynx or voice-box of terrestrial Vertebrates are also derived from this source, in part at least. These are admirable examples of "change of function" (p. 13).

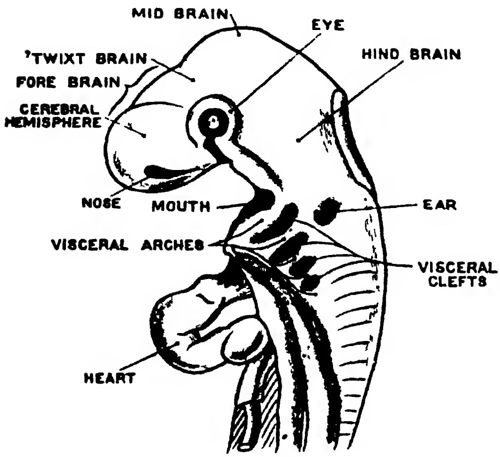


Fig 151.—Front part of Chick Embryo

The *breathing-organs* (fig. 150) of the adult Salamander have already been spoken of in the foregoing, but it may be added that the lungs and air-passages agree fairly well with what has

been described for the Sand Lizard (see p. 191). The provision for renewal of air in the lungs is, however, different, for there is here no means of altering the capacity of the chest by movements of ribs and sternum, air being in this case renewed in the lungs by the upward and downward movement of the floor of the mouth-cavity. During this process the mouth is kept shut, air passing from and to the exterior through the nose, which opens externally by valvular nostrils and internally by small apertures on the roof of the mouth

The Salamander, too, is not altogether dependent on the lungs for the purification of its blood, as the moist skin also serves as an accessory breathing-organ, the blood which it purifies entering the great veins which pour impure blood into the sinus venosus. This blood is therefore less impure than would otherwise be the case

The *brain* (fig 150) is much like that of the Sand Lizard, but is of lower type, it being especially noticeable that both cerebral hemispheres and cerebellum are smaller in proportion. As regards the chief *sense organs*, the eye is not provided with a third eyelid, and its crystalline lens is spheroidal instead of being biconvex as in animals better adapted for a terrestrial life The ear on each side consists essentially of a membranous labyrinth not unlike that found in a Lizard (see p. 203). There are, however, no special arrangements, for conducting sound-waves. This, however, is not a feature which characterizes all Amphibia, the frog, for example, having a tympanic cavity and tympanic membrane, and a small rod, the columella or ear-bone, running from that membrane to the part of the skull in which the membranous labyrinth is lodged.

The Amphibia now living are divided into three orders— 1. Urodela, or Tailed Amphibia; 2. Anura, or Tailless Amphibia; and 3. Gymnophiona, or Limbless Amphibia.

Order 1.—Tailed Amphibians (Urodela)

Salamanders, Newts, and allied forms are here included (fig. 152). The Spotted Salamander (*Salamandra maculosa*), just described, is a good example of the Urodela. Its relative, the Black Salamander (*S. atra*), is a smaller Alpine form, and other allied species inhabit the Peninsula and the Caucasus.

Newts or *Efts* differ from Salamanders proper in the possession of a tail flattened from side to side and used as a swimming organ. Running round the margin of the tail is a fin like expansion, which, however, is not supported by hard parts as in a fish. Three kinds are native to Britain, and constitute our only representatives of the tailed Amphibia. Of these the

Fig. 52. Tailed Amphibia.—Spotted Salamander [illegible]

commonest is the Small Newt (*Triton tæniatus*) which is only a little more than 3 inches long. The upper surface and sides are olive-coloured with dark spots and streaks while the paler under side is marked by a longitudinal orange coloured band. The male has a fin like crest running down the middle line on the upper side of the trunk, and continued into a similar fold which margins the tail the colouring and marking are not quite the same as in the female. Another British species the Crested Newt (*Triton cristatus*), may be more than 5 inches long and the crest on the back of the male is much better developed. The only other species found in this country, and that less frequently, is the Webbed Newt (*Molge palmata*), which is not more than 3 inches long. There are no spots on the under surface, and the hind-feet of the male are webbed.

The largest living Amphibian is the Giant Salamander (*Megalobatrachus maximus*) from Japan and China which is commonly 3 feet long, and is said to attain a still greater size

Fig 15 The Ol [illegible]

It is a clumsy looking creature, with a huge flattened head, broad rudder-like tail, and short, unfinished-looking limbs The body is covered with a dark leathery skin, raised into numerous warts, and exhibiting a thick wavy fold on each side. This creature is a representative of a group of forms known as "Fish Newts" in which the trunk is long and the limbs weak, while other

primitive characters are present, such as biconcave centra to the vertebræ, eyelids represented by a circular fold and (except in the Giant Salamander itself) persistent remains of a gill breathing condition, seen, it may be, in the actual retention of gills along with the lungs, or of a pair of gill-slits in the throat

Fig. 154.—The Axolotl

Adult salamander form (*Amblystoma tigrinum*) above; larval or axolotl form (*Siredon mexicanum*) below.

The Hell-Bender, or Salamander of the Mississippi (*Cryptobranchus lateralis*), has a pair of gill-clefts, or sometimes one on the left side only. The Three-toed Salamander (*Amphiuma means*), from the same river, is eel-like in shape, with very small weak limbs, terminating in three or it may be only two digits. A pair of gill-slits are present.

The flesh-coloured Olm (*Proteus anguineus*) (fig. 153) is a remarkable eel-like form, about 10 inches long, which inhabits the underground lakes and streams of certain caves in Dalmatia, Carniola, and Carinthia. Both fore- and hind-limbs are very small, and furnished respectively with three and two digits. Coral-coloured external gills are present as well as two pairs of gill-slits. The eyes are small and concealed beneath the skin. Much longer (28 inches) than the Olm is the Siren (*Siren lacertina*) of the south-east part of the United States. The dark-coloured body is extremely eel-like and the hind-limbs are entirely absent, while the four-toed fore-limbs are very small External gills and three pairs of gill-slits are present.

One of the most interesting Urodeles is the Mexican Axolotl (fig 154), which in what must be called the adult state is a thorough-going Salamander, known as *Amblystoma tigrinum*, and in the United States, to which the range of the animal extends, this adult condition is reached. In the lake surrounding the city of Mexico, however, this is not the case, and the Axolotl permanently remains in the larval state, resembling an enormous newt tadpole. Gill slits and external gills are present, and eggs are laid just as by adults We have here the astonishing phenomenon of an animal which, so to speak, is dropping the adult stage out of its life history, the conditions being unfavourable for its development We only know this by accident, and the precocious tadpoles were, when first described, thought to be adult, receiving the name of *Siredon Mexicanus*. There are doubtless other still undetected cases of this remarkable phenomenon in the animal kingdom.

Order 2 Tailless Amphibians (Anura)

While the Tailed Amphibia are confined to the Northern Hemisphere, the Frogs and Toads, which constitute the group of Tailless Amphibia, are cosmopolitan. The Grass Frog (*Rana temporaria*), which is one of the most familiar British Vertebrates, is a good type of one of the most widely-distributed families of the order, and a brief description of its more obvious external characters (fig. 155) will illustrate the differences which distinguish animals of the sort from Salamanders and their allies.

The flattened triangular head, with rounded snout, passes

into a short plump body without any intervening neck-region. In the adult animal there is absolutely no trace of a tail, though this is well-developed in the larval form or tadpole, a fact which no doubt points to the descent of Frogs from tailed ancestors. The limbs are much better developed than in the Salamander, but the hind-limbs, which serve both as leaping and swimming

Fig. 155. Tailless Amphibia.
Grass Frog (*Rana temporaria*), above; Common Toad (*Bufo vulgaris*), below.

organs, are out of all proportion large as compared with the fore-limbs. Four digits only are externally visible in the latter, there being no apparent trace of a thumb, but the hind-limb possesses five well-developed toes, between which a delicate web extends. A very curious feature is the presence of a little horny spur, the *calcar*, on the inner side of the foot, and examination of the skeleton shows that this is really an extra digit, though in a much-reduced condition.

Nostrils and eyes are present closely resembling those of a Salamander, but behind either eye may be seen a well-marked rounded area corresponding to the tympanic membrane covered over by skin. A small rounded cloacal aperture is present at the hinder end of the trunk. The skin is soft and moist, as in Amphibians generally, and is entirely devoid of hard parts, with the trifling exception of the horny spur on the foot. The upper surface is mottled and the under surface pale, and, as in the Chameleons, though not quite to the same extent, the animal has the power to adjust its colour so as to match the surroundings for the time being. A frog which has been kept for some time in a dark place becomes almost black in colour, but if the same animal is transferred to grass it will gradually assume a greenish tint.

Endoskeleton (fig. 156). The peculiarities of the *skull* cannot be entered into here, but as regards the *backbone*, it may be said that the number of vertebræ is reduced to ten, their centra, too, being concave in front and convex behind, as in Reptiles. The first vertebra is a ring-like *atlas*, and the last fulfils the function of a *sacrum*, being connected with the hip-girdles supporting the hind-limbs. The hinder end of the backbone is completed by a bony rod, the *urostyle*. No separate *ribs* can be distinguished, but there is reason to believe that the prominent transverse processes which project from the sides of the vertebræ are partly equivalent to these. It is quite a common thing for ribs to fuse with vertebræ, at least in certain regions, *e.g.* in the human skeleton short neck-ribs have undoubtedly been soldered, so to speak, with the vertebræ which support the neck.

The *sternum* is much better developed here than in the Salamander, and is closely connected with the *shoulder-girdles*. These present the typical regions, but it may be noted that the precoracoid bar is covered over by a collar-bone or clavicle. The skeleton of the rest of the *fore-limb* corresponds fairly well with the pattern limb (see pp. 196–198), and a vestige of the thumb can be made out. The forearm, however presents a very interesting case of fusion, for its two typical bones, the radius and ulna, are here closely united together. In the *hind-limb* a number of instructive variations on the pattern form are to be seen. The *hip-girdles* are quite unlike the corresponding parts in a

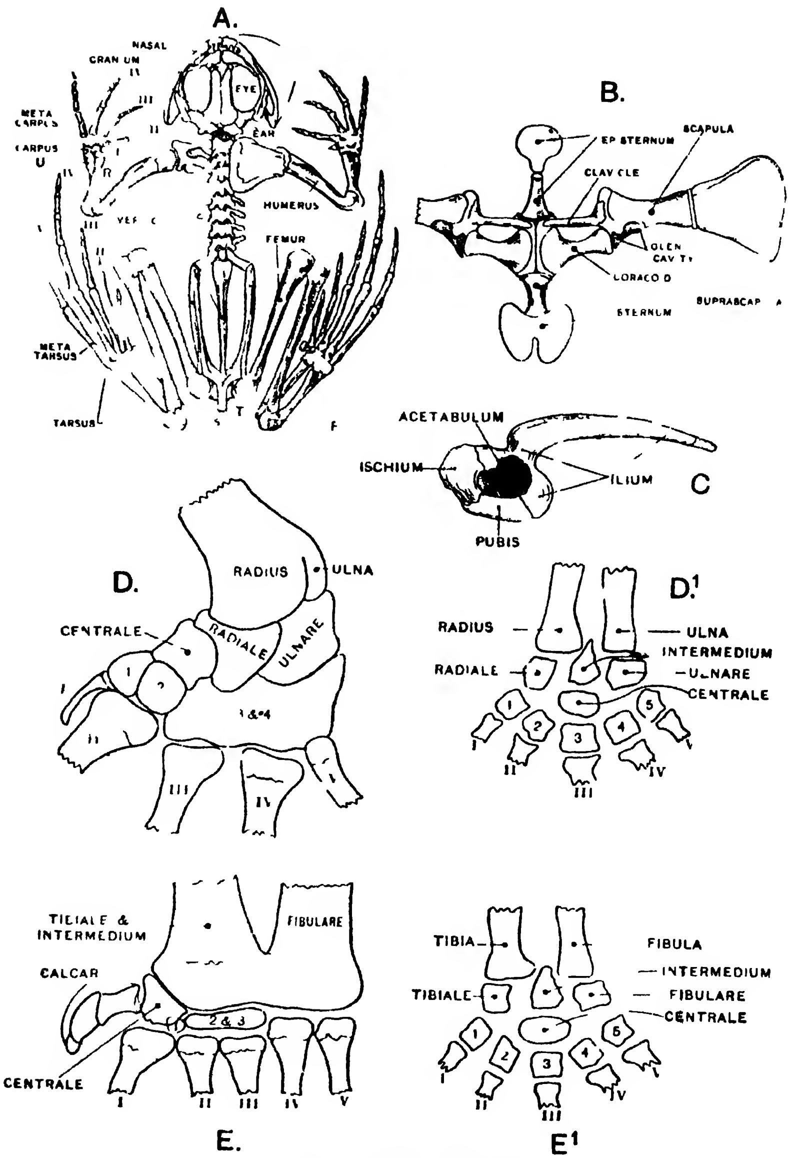


Fig 1 6.—Skeleton of Frog

A Skeleton seen from above (R radius U ulna IL ilium IS, ischium T tibia F fibula * calcar) B, Sternum and shoulder girdles C Right hip girdle from side. D Wrist D Pattern wrist E, Ankle F Pattern ankle.

Salamander. They are very intimately united into a forked bone, of which the forwardly-directed prongs are the ilia. The bones of the free limb are longer in proportion than in the fore-limb, and the bones of the lower leg, tibia and fibula, are fused together just like the radius and ulna in the fore-limb. Great specialization has taken place in the *tarsus*, for while that part of it next the fused tibia and fibula is represented by two elongated bones (= tibiale and fibulare) the rest has dwindled

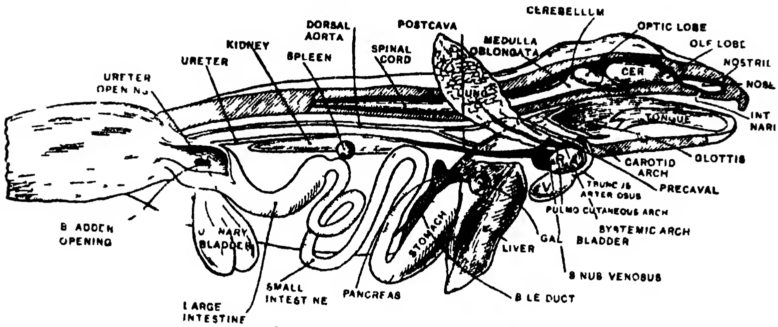


Fig. 157. General Structure of Frog

away to insignificant vestiges All this is to fit the limb for its use as a leaping organ, and changes of similar kind are seen in certain Mammals which use the hind-limbs in the same way. It is another illustration of the close connection which exists between form and function, though much space would be required to work it out in detail, even had we all the necessary data, which does not appear to be the case.

Broadly speaking, the *digestive organs* (fig. 157) agree with those of the Salamander except as regards the teeth and tongue The *teeth* are entirely absent from the lower jaw, though they fringe the upper jaw, and occur in two small groups on the roof of the mouth. The long forked *tongue* has the remarkable peculiarity of being attached to the front of the mouth-floor, with its tip pointing backwards when not in use. It is an insect-catching organ of no mean order of perfection, which can be whipped out of the mouth with great rapidity and as rapidly drawn back, generally carrying with it the desired booty.

The *circulatory organs* are built on the same type as those of the Salamander (see p. 240), and keep the impure and pure blood separate to the same extent, supplying the former to lungs

and skin for purification and the latter to the head, while the greater part of the body has to put up with mixed blood. There are, however, numerous minor differences, one of the most striking being the presence of three pairs of aortic arches as against four, those corresponding to the third pair in the Salamander having disappeared.

The *lungs* are similar in nature to those in the Salamander (see p. 244), being a pair of bags, the linings of which are raised into a honeycombing of ridges. The supply of air of the lungs is renewed in the same way, by a pumping action in the mouth-cavity, the floor of which is alternately raised and lowered.

The only points in the *nervous system* and *sense organs* which need be noticed are the extreme shortness of the spinal cord and the presence of a sound-conducting middle ear not unlike that present in the Sand Lizard (see p. 192).

The *life-history* of the Frog is extremely interesting. From the eggs are hatched fish-like limbless tadpoles, in which the breathing organs are at first *external gills*, like those of the larval Salamander (see p. 240). After a time, however, these begin to shrivel and are replaced by the so-called *internal gills*, consisting of folds on the walls of the four pairs of gill-clefts, quite unlike anything found in the Tailed Amphibia but closely resembling the gills of some fishes. As these gills develop, a fold of skin grows backwards over the gill-slits and unites to the body behind them, leaving only a small round hole on the left side through which is expelled the water that has been taken in at the mouth and passed through the gill-slits. The adult form is reached by growth of limbs, accompanied by loss of tail and closure of the gill-slits, the lungs assuming their adult function. There is also a change in the nature of the food, for a tadpole is a vegetarian while the adult frog lives on insects and other small animals.

The Grass Frog has a wide distribution through Europe and non-tropical Asia, while the family (Ranidæ) to which it belongs is represented in all parts of the world except New Zealand and Polynesia. The well-known Edible Frog of the Continent (*Rana esculenta*) is common in the east of England, but has most likely been introduced. Much larger species of the same family are the Bull Frog (*Rana Catesbyana*), inhabiting the east of North America and attaining a length of over 7 inches.

while Guppy's Frog (*Rana Guppyi*) from the Solomon Islands is nearly a foot long.

The Common Toad (*Bufo vulgaris*) is a more sluggish animal than the Grass Frog, and better adapted to a terrestrial life (fig. 155). Its skin is dull and warty, and prominent neck-glands like those of the Salamander are present. Teeth are entirely absent. The range of this species is even wider than that of the Grass Frog, for it is found in North-west Africa as well as in Europe and Asia.

Another species of toad found in Britain, though less frequently than the ordinary kind, is the Natterjack (*Bufo calamitata*), readily distinguished by a yellow or whitish streak down the middle of the back. The family to which both these toads belong (Bufonidæ) is almost as widely distributed as the Ranidæ, but is absent from Madagascar and rare in the Australian region.

There are thirteen other families of the Tailless Amphibia besides those mentioned, but none of them are so widely distributed, and some have a very restricted range.

Order 3.—Limbless Amphibians (Gymnophiona)

The remarkable modifications which have taken place in the bodies of some Fish-Newts, such as the Siren (see p. 248), are carried a step further here, for the tropical worm-like creatures (fig. 158) which make up the order are entirely limbless, tailless, and modified in other ways for a burrowing life. The body of a Cæcilian is encircled by grooves, and in some species small bony plates are imbedded in the skin. The small mouth is provided with sharp backwardly-curved teeth suited for the capture of earth-worms, insects, and other small creatures. The

Fig. 158.—A Cæcilia, *Siphonops annulata* from tropical America

vertebræ exhibit the primitive feature of biconcave centra, and small movable ribs are attached to them. There is no sternum, and even the limb-girdles are absent. As in Snakes, some of the internal organs are modified to suit the narrow shape of the body, and it may be mentioned in particular that the right lung is much larger than the left. In regard to the sense organs, it may be noticed that the small eyes are hidden under the skin and the sound-conducting middle ear is absent. The development of an East Indian form (*Epicrium glutinosum*) has been studied, and presents some curious points. When the embryo is hatched it possesses three pair of external gills, a pair of gill-slits, a short tail, and traces of hind-limbs. Immediately hatching takes place, however, these gills are lost; but in spite of this the larva takes to the water and lives there for some time.

BUTTERFLIES (*Rhopalocera*)

Butterflies and Moths together constitute the order of Scale-winged Insects (*Lepidoptera*), in which the four wings are opaque and coloured, owing to the presence of minute dust like scales. Typical Butterflies are diurnal in habit, their antennæ are club-shaped, and they bring the wings together above the back when they settle. Those figured are among the most attractive of tropical and British species, belonging to the Fritillaries (1–4) and Swallow-tails (5, 6).

1. Giant Blue (*Morpho cypris*) } Tropical America
2. Resplendent Ptolemy (*Morpho neoptolemus*) } Tropical America
3. Purple Emperor (*Apatura Iris*), oakwoods in the southern English counties.
4. Peacock Butterfly (*Vanessa Io*), Europe (including Britain) and N. Asia to Japan.
5. Common Swallow tail (*Papilio machaon*), ranges from Britain to the Himalayas.
6. Imperial Swallow-tail (*Teinopalpus imperialis*), male; in the female each hind-wing has two tails. Sikkim.

BUTTERFLIES (RHOPALOCERA)

1 Giant Blue 2 Resplendent Ptolemy 3 Purple Emperor 4 Peacock Butterfly
5 Common Swallow-tail 6 Imperial Swallow-tail

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CHAPTER VI

STRUCTURE AND CLASSIFICATION OF FISHES AND PRIMITIVE VERTEBRATES

The 7300 odd species of existing fishes known to science are divided into the following five sub-classes:—

I. Lung-Fishes (Dipnoi).
II. Bony Fishes (Teleostomi).
III. Sharks and Rays (Elasmobranchii).
IV. Chimæras (Holocephali).
V. Round-Mouths (Cyclostomata).

Probably the best idea of the general structure of the group will be obtained by briefly describing such a common example of the Shark kind (Elasmobranchs) as the Spotted Dog-Fish (*Scyllium canicula*), abundant on our shores, especially during the herring season. It may to all intents and purposes be regarded as a small shark.

External Characters (fig. 166).—The spindle-shaped body is well suited for progression through the water, and its outline is continuous, there being no sharp boundary between head and trunk, or trunk and tail. We have seen that in tadpoles and some adult Amphibia (see p. 246) there is a membranous fringe bordering the tail above and below and running forwards on the upper side of the trunk. Such a longitudinal fringe running in the middle line is known as an *unpaired fin*, and is especially characteristic of Fishes, where, however, it is not a mere soft membrane as in Amphibia, but is supported by firm rod-like structures, the *fin-rays*. We find that in the Dog-Fish, as in most fishes, this membrane is not continuous, but is represented by a number of separate pieces, each of which is named with reference to its position. Here, for example, there is a *caudal fin* bordering the tail, two *dorsal fins* in front of this above, and an *anal* or *ventral fin* in front of it on the under side. Special attention may be called

to the tail-fin, which is unsymmetrical, consisting of a large upper lobe into which the slender end of the body is continued, and a smaller lower lobe. Such unequal or *heterocercal* (Gk. *heteros*, diverse; *kerkos*, tail) tails are shown by reference to fossil forms to be of very ancient type. There is good reason to believe that remote fish-ancestors had a continuous unpaired fin, of which the existing ones are fragments which have been retained and enlarged to suit special purposes. The Dog-Fish, however, also possesses *paired fins*, consisting of two large *pectorals* in front and two smaller *pelvics* placed close together farther back. These are the equivalents of the fore- and hind-limbs of the terrestrial vertebrates so far described, but differ in important respects in accordance with differences in use. The limbs of a Salamander, for instance, have to support the weight of the body and are the means of progression. The presence of digits is of obvious advantage as regards the former, while locomotion would be difficult and awkward were the limbs not transversely divided into regions capable of being moved upon one another. But the limbs of an ordinary fish do not support the body, and their chief use seems to be that of steadying it in the water and directing its movements. For these purposes the undivided paddle-like shape which we associate with the paired fins of a fish appears best adapted.

The large curved *mouth* is situated on the under side of the head, and not far in front of it are the rounded *nostrils*, each of which is connected by a groove with the corresponding corner of the mouth. Far back on the under surface of the body, and marking the junction of trunk and tail, is a rounded *cloacal aperture* situated between the pelvic fins. On each side of this opening is a small aperture known as an *abdominal pore*, of unknown use, but commonly found in more than one group of fishes. The oblique cat-like *eyes* are provided with imperfectly movable upper and lower eyelids. A tadpole, it will be remembered, has four gill-slits on each side of the throat, the cavity of which is thus placed in communication with the exterior. Here there are five *gill-slits*, and also a superseded gill-slit known as the *spiracular cleft* and opening behind the eye by a small round hole, the *spiracle*.

The *skin* is of a brownish hue, much darker above than below, and marked with good-sized roundish spots. Projecting

from the surface are the sharp points of innumerable small hard structures, closely resembling teeth in structure and usually known as *placoid scales.* The presence of these causes a peculiar roughness suggestive of sand-paper. Numerous sense organs are present in the skin, some of which will be alluded to farther on.

The first point of general interest to note with regard to the *internal skeleton* (fig. 159) is that it is entirely made up of

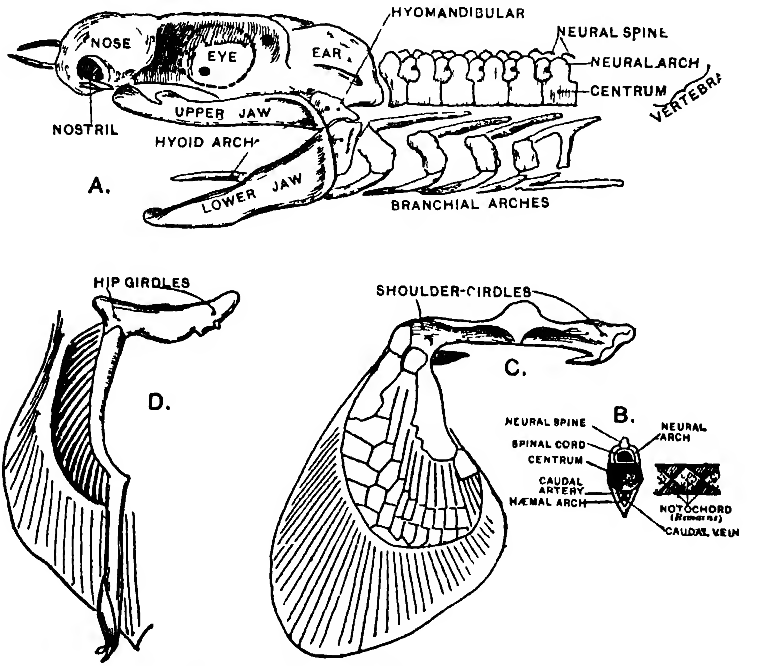


Fig 159 —Skeleton of Dog Fish (*Scyllium canicula*)

A, Skull and part of vertebral column B End view of a caudal vertebra, and longitudinal section through centra of two vertebræ C, Pectoral fin (from below) D, Pelvic fin (from below)

cartilage and fibrous tissue, as generally in what are called "cartilaginous fishes", while in ordinary "bony fishes", including all the common edible forms, a great deal of bone is present as well as more or less cartilage.

The *skull* is extremely simple compared with that of the higher animals so far considered, and consists of a brain-case to which are attached protective capsules for nose and internal ear, the framework of the jaws, and what is known as the

"visceral skeleton". Regarding the last two a little more may be said, as they have much to do with the visceral arches and clefts which are so characteristic of Vertebrates, and have been so often alluded to in the foregoing pages (see pp. 62 and 242).

Examination of a young embryo of the Dog-Fish will show that on each side of the head there are seven oblique bar-like thickenings and six slits occupying the interspaces between them. These are respectively termed *visceral arches* and *clefts*, the hindermost five having the special name of gill arches and clefts because the gills are developed in connection with them. The first arch is the ***mandibular arch*** and the second the ***hyoid arch***, while the slit between them is naturally called the ***hyo-mandibular cleft*** and is no other than the spiracular cleft of the adult. These various arches are traversed and supported by firm jointed rods forming part of the internal skeleton. The mandibular arch is so called because it becomes the mandible or lower jaw, while the upper jaw is a forward outgrowth from it. The skeleton of the rest of the arches constitutes the *visceral skeleton*, which stiffens the gill region and prevents the gill-slits from becoming closed, giving also firm points of attachment to many muscles. A special function is performed by the upper joint of the skeleton of the second or hyoid arch, this being a stout piece of cartilage (hyomandibular cartilage) which slings the jaws to the main skull. In Vertebrates higher than Fishes this cartilage loses its original function, for the jaws are directly attached to the skull, and most probably some or all of the little ear-bones, which help to conduct sound-waves across the drum of the ear in such higher Vertebrates, correspond to this cartilage. This is one of the best examples known of a change of function. The rest of the visceral skeleton, here so important in connection with the gill-clefts, dwindles in air-breathing Vertebrates to the "hyoid apparatus", which has been so often mentioned (see pp. 29, 193, and 239) as supporting the base of the tongue in these forms, and to the cartilages which support the voice-box or larynx. In the life-history of the frog the passage from a well-developed visceral skeleton in the gill bearing tadpole to such remnants in the adult lung-possessing animal can be traced step by step.

In the *vertebral column* it is only possible to distinguish between trunk-vertebræ and tail-vertebræ, and all these possess biconcave centra, which may be regarded as the most primitive

kind. Short *ribs* can be distinguished in the trunk, but there is no trace of any sternum.

The skeleton of the *paired fins* exhibits many differences from the supporting parts of the limbs of terrestrial Vertebrates, and comparison between the two is extremely difficult. In the pectoral fin there is a very simple *shoulder-girdle*, consisting of a curved piece of cartilage running transversely and fusing with its fellow in the middle line below. At the base of the free part of the fin are three cartilages, followed by a number of others, and these again by jointed *fin-rays*. In the pelvic fins the two *hip-girdles* are represented by a simple transverse bar, while the free fin is supported by a stout rod bearing a large number of fin rays.

Digestive Organs (fig. 160)—The jaws are bordered by numerous rows of small pointed *teeth*, all much alike, and replaced by fresh ones during life as often as necessitated by wear and tear. These teeth are not suited for chewing, but for seizing such prey as small fish, crustaceans, &c., and afterwards preventing their escape. Around the margins of the mouth we find all gradations between ordinary placoid scales and teeth, which is intelligible when we recollect that the cavity of the mouth is developed as a pit on the surface of the body. The lining of such a pit, or inpushing of the general surface, so to speak, is evidently equivalent to skin, and teeth here and elsewhere are simply more or less modified scales, developed within the margins of the mouth. The *tongue* is merely an immobile fold on the floor of the mouth The nasal organs do not possess internal nostrils as in the lunged vertebrates. The cavity of the mouth passes behind into a wide *pharynx*, out of which the spiracular cleft and gill-clefts open; and then follow gullet, U-shaped stomach, and intestine opening into a cloaca. There is no clear distinction, as in forms so far considered, between small and large intestine. Within this intestinal part of the gut is a so-called *spiral valve*, which is simply a projecting shelf winding round and round and presenting a large surface for the absorption of digested fo[illegible] A large *liver* pours bile into the beginning of the intestine, and there is also a *pancreas* opening not far from it.

Circulatory Organs (fig. 160).—Here we have the same conditions as in the Tadpole before the lungs begin to be of

use, and the conditions are consequently comparatively simple, the problem of separating two kinds of blood not having yet arisen. The *heart* consists of a thin-walled venous sinus, which receives the impure blood of the body and passes it on to a single auricle, by which it is squeezed into a thick-walled ventricle, continued again into a muscular tube, the arterial cone. Valves to prevent the blood from running back the wrong way are placed at the points of junction between sinus,

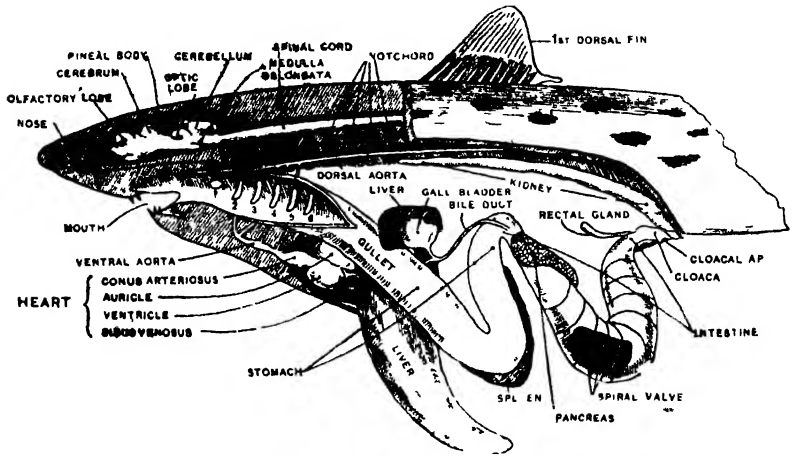


Fig. 160.—Side-dissection of Dog-Fish (*Scyllium canicula*). Left half of liver has been removed. 1, Internal opening of spiracular cleft. 2, 3, 4, 5, 6, Internal openings of gill clefts.

auricle, and ventricle, and several transverse rows of valves are present in the arterial cone. From the *ventral aorta*, which runs forward from the cone, five pairs of *afferent* gill-arteries run out and carry impure blood to the gills, from which five pairs of *efferent* gill-arteries conduct the purified blood, uniting above to form the *dorsal aorta* that runs back to the end of the tail, giving off numerous vessels by which the various organs and regions receive their pure blood-supply. Each afferent artery, with its corresponding efferent one, may be looked upon as constituting an *aortic arch* (see p. 242).

Breathing-organs (fig. 160).—Upon the walls of the five pairs of gill-slits, or pouches, to speak more correctly, numerous closely-set gill-folds are placed, and in these folds there are very numerous capillary blood-vessels, with which the gill-arteries are in communication. Water is constantly taken in

at the mouth, and, passing back, streams outwards through the gill-pouches—thus passing over these folds, which collectively present a large surface over which the oxygen dissolved in the water can diffuse into the blood, while the waste carbon dioxide of the blood can diffuse outward into the water and be carried away to the exterior.

In this connection great interest attaches to the spiracular cleft, which looks very much like a narrow gill-pouch, and on close examination is seen to have a number of small folds on its front wall. These are so gill-like that they have been collectively called a *false gill* (pseudobranch), and when it is added that some few fishes possess a properly-developed set of gill-folds in this place, it will be clearly seen that the spiracular cleft is really a gill-cleft which is losing its function. There is every reason to believe that the cavity of the middle ear in higher Vertebrates, together with the Eustachian tube, is equivalent to the spiracular cleft. Here, then, is a structure which once had to do with breathing and is now concerned with sound conduction—another excellent example of change of function.

Nervous System and Sense Organs (fig. 160).—The *brain* is pretty well developed, a peculiar feature being that the two cerebral hemispheres are represented by an unpaired swelling, while the olfactory lobes are placed on stalks. The cerebellum is much larger than in Amphibia.

The *eyeball* is flattened on the outside and its crystalline lens is approximately spherical, as in aquatic animals generally. Probably everyone has noticed, some time or other, the lens in the eye of a cooked bony fish, such as salmon or herring, looking, as it does, like a sugar-coated pill. Needless to say, the opacity is the result of cooking. Here, too, the lens is spheroidal. The *organs of hearing* consist simply of the internal ear or membranous labyrinth, contained in a gristly capsule on either side of the back end of the brain-case. In shape the labyrinth is somewhat simpler than in the Amphibia. The *skin* contains a large number of sense-organs, some of which are sunk in a tube which runs along each side of the body and opens to the exterior at intervals. An external streak, the *lateral line*, marks the position of either tube, but this is much better seen in a bony fish than in the Dog-Fish. There are also peculiar *jelly-tubes* which open by regularly arranged pores

on the under side of the head, and undoubtedly have to do with sensation. Little is known of the use of these organs, but they no doubt respond to certain vibrations in the surrounding water. It is important to avoid the common error, made when dealing with the sense organs and sensations of lower animals, of trying to explain them by reference to ourselves.

Development.—The Dog-Fish is developed from an egg, which looks almost like the "yolk" of a fair-sized bird's egg were it not for its greenish tint. This egg is enclosed in a horny "purse", the corners of which are drawn out into tendril-like threads which curl round sea-weeds and other firm objects.

We may now proceed to the consideration of the chief groups of Fishes.

Sub-class I.—LUNG-FISHES (Dipnoi)

Of all known fishes these come nearest to the Amphibia, and some zoologists place them in a class of their own, distinct from that containing more ordinary fishes. They are a very ancient group, now represented by only three genera, all of which are found in fresh water. They are the Barramunda or Burnett Salmon (*Ceratodus*) from the Burnett and Mary rivers in Queensland, the African Lung-Fish (*Protopterus*), native to some of the rivers of tropical Africa; and the South American Lung-Fish (*Lepidosiren*), found in the Amazon and upper part of the Paraguay rivers and their tributaries (fig. 161).

There are certain characters common to all three forms. Taking first the *external characters*, the head is somewhat amphibian-like, and has been compared to that of a salamander, while the tail tapers considerably and is symmetrically margined by a fin which is not expanded into lobes (protocercal or diphycercal caudal fin). There is no spiracle, but gill-clefts are present, protected by a flap or *gill-cover*. The paired fins are much elongated, and the body is covered by thin overlapping scales.

The most characteristic feature of the internal organs is the presence of one or two bag-like *lungs* opening on the under side of the pharynx, so that these animals possess, like some adult Amphibia, both gills and lungs at the same time, and it is from this circumstance that they derive the name of Dipnoi (Gk. *dis*, twice; *pnoe*, breath).

Since the heart receives pure blood from the lung or lungs, as well as impure blood from the general body, the problem of separating the two kinds demands solution; but this is only effected in an imperfect manner, for there is not even, as in Amphibia (see p. 240), a complete separation of the two auricles which are here present.

These are the only fishes in which there are *internal nostrils* as well as external ones. They open just within the margin of

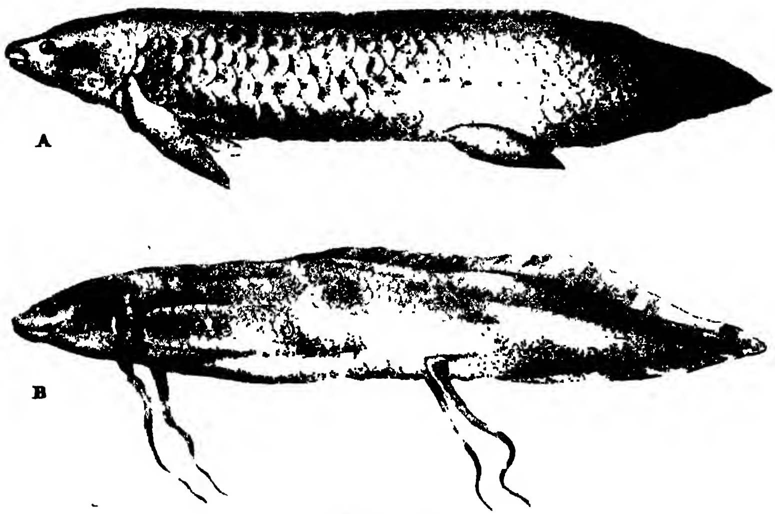


Fig. 161.—Dipnoi
A, Australian Lung-Fish (*Ceratodus*), × ¼ B, African Lung-Fish (*Protopterus*), × ¼.

the upper lip. The mouth is provided with large dental plates of peculiar form.

Ceratodus is a large broad fish, attaining the length of 4 or 5 feet, and with its body covered by very large scales. The paired fins are broad and paddle-shaped, and each of them is supported by a central axis made up of numerous joints, and of a series of fin-rays attached to the axis in front and behind in a feather-like way. *Protopterus* is much more slender in form and its paired fins are extremely narrow, the fin-rays on the central axis being largely suppressed. Some specimens are said to reach a length of 6 feet. There are small external gills as well as the gill-folds on the walls of the gill-clefts. *Lepidosiren* is an eel-like form which may be as much as 6 feet long. Its

paired fins are even narrower than those of Protopterus, and supported only by a central jointed axis.

SUB-CLASS II.—BONY FISHES (TELEOSTOMI)

This large group of fishes includes a vast number of recent and fossil forms which present such varying characters that it is difficult to give a satisfactory definition. There is, however, a good deal of bone in the skeleton, and the jaws, instead of being mere bars of gristle, as in a Dog-Fish, are ensheathed by tooth-bearing bones in the same way as in higher forms. The gill-clefts are very near together, and the gill-arches between them are comparatively narrow, so that the gill-folds as seen in a Dog-Fish are not supported along the whole of their length, but project more or less to the exterior as free *gill filaments.* The gill-clefts are covered over and protected by a flap, the gill-cover or *operculum,* which is supported by bones. Two orders may be distinguished.—1. Ganoids, and 2. Bony Fishes proper or Teleosts.

Order 1.—GANOIDS (Ganoidei)

Under this name are included a number of recent genera, widely scattered over the globe, and for the most part limited to fresh water (fig. 162). They are the last surviving remnants of groups which were once of great importance, but which have been unable to compete with more highly-organized fishes, and have greatly declined in consequence. Of recent forms the two most primitive are the Bichir (*Polypterus*) of the Nile and some other African rivers, and the Reed-Fish (*Calamoichthys*) from the rivers of Old Calabar. The former is a remarkable-looking creature of respectable size, being as much as 4 feet long. Running along the back are a considerable number of little dorsal fins, each with a strong spine in front, while the last of them abuts against the rounded protocercal fin of the tail, close to which, on the under side, is an anal fin. The paired fins consist of a thickened basal part, supported by cartilages something like those described for Dog-Fish (see p. 261), and fringed by a thinner region supported by radiating fin-rays. The body is covered by thick lozenge-shaped bony plates (ganoid

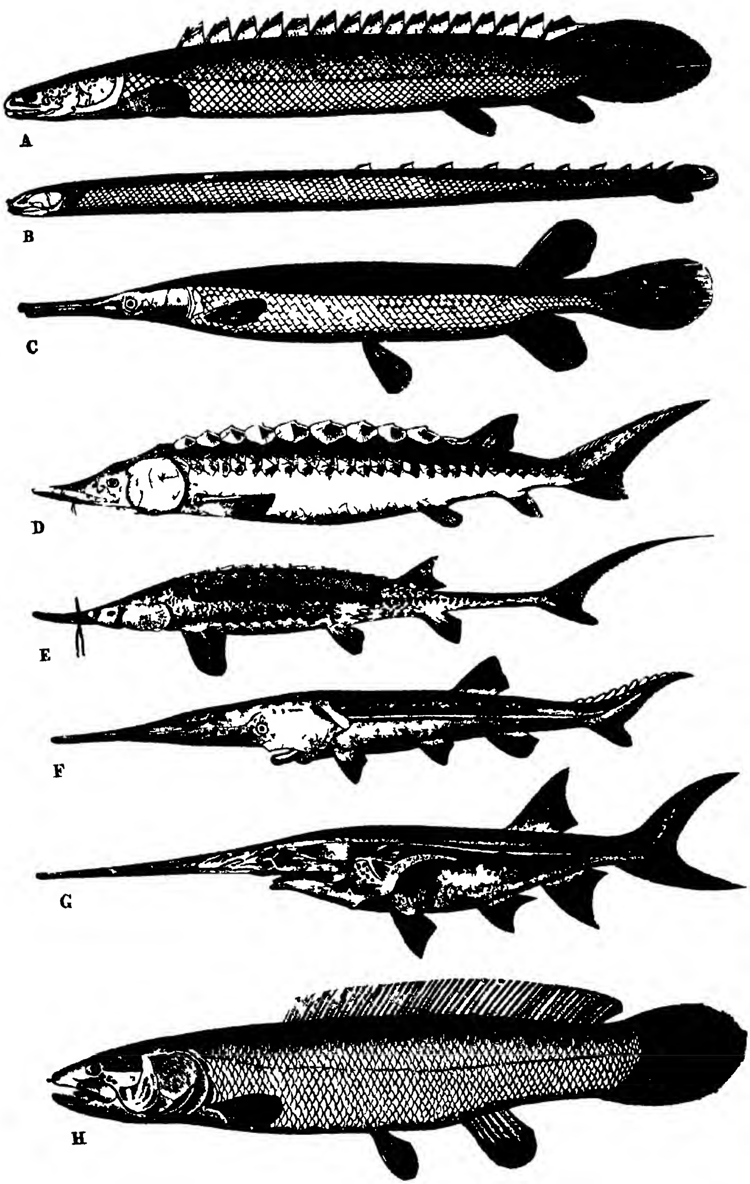


Fig 162 —Ganoids

A, Bichir (*Polypterus*), $\times\frac{1}{5}$ B, Reed-Fish *Calamoichthys*), $\times\frac{1}{3}$ C Gar-Pike (*Lepidosteus*), $\times\frac{1}{8}$ D, Common Sturgeon (*Acipenser*), $\times\frac{1}{16}$ E, Shovel nose Sturgeon (*Scaphirhynchus*), $\times\frac{1}{8}$ F, Slender-beaked Sturgeon (*Psephurus*), $\times\frac{1}{8}$ G Spoonbill Sturgeon (*Spatularia* or *Polyodon*), $\times\frac{1}{8}$ H, Bow Fin (*Amia*), $\times\frac{1}{10}$.

scales), united firmly by their edges and having a very regular arrangement in oblique rows, while the head is covered by paired bony plates.

The Reed-Fish is what a small Bichir might be imagined to become if it were pulled out into an eel-like form and lost its pelvic fins.

Both these forms are distinguished as "Fringe-finned" Ganoids on account of the structure of the paired fins; while the remaining recent Ganoids are "Ray-finned", *i.e.* the paired fins have lost the thickened basal portion and consist of a fan-like expansion strengthened by the numerous diverging fin-rays, which may be compared to the sticks of the fan. These ray-finned forms include the Gar-Pikes, Sturgeons, and Bow-Fins of the present day.

The Gar-Pike (*Lepidosteus*) is common in the fresh waters of North America, and may be as much as 6 feet long. Covered with firm armour like the Bichir, it differs not only in the structure of the paired fins, but also in the presence of a single dorsal only, while the head is drawn out into long but powerful jaws.

Sturgeons are large fishes which have lost more or less of the dermal armour, have a much elongated snout, and an unsymmetrical tail like that of the Dog-Fish (see p. 258). The mouth is on the under side of the body, at the base of the snout. The Common Sturgeon (*Acipenser*) includes some twenty species, of which the largest, a Russian form, is as much as 30 feet in length. It is distinguished by its broad pointed snout, on the under side of which are four sensitive thread-like structures (barbels), and the presence of rows of broad keeled plates in the skin. Sturgeons of this kind are widely distributed through the fresh waters and along the coasts of the Northern Hemisphere. One species (*Acipenser sturio*) is British, and may occasionally be seen in fishmongers' shops.

The Shovel-nose Sturgeon (*Scaphirhynchus*), native to the Mississippi and the rivers of Central Asia, is of more elongated form than the common form, and its dermal armour is more complete, especially in the hinder part of the body.

The two remaining kinds of Sturgeon both have teeth, while the sorts so far mentioned are toothless; and they are further distinguished by enormous snouts and the complete, or almost complete, absence of armour. One, the Slender-beaked Sturgeon (*Psephurus*) of the Yang-tse-Kiang and Hoang-ho rivers has a

conical snout, and the other a broad flattened one, as is indicated by the name of Paddle-Fish or Spoon-bill Sturgeon (*Spatularia*). It is found in the Mississippi.

The last remaining recent Ganoid, the Bow-Fin (*Amia*), resembles the ordinary bony fishes in many respects, and was for long confused with them. Its body is covered by thin overlapping flexible scales. In distribution it corresponds to the Gar-Pike.

One structural feature in which all these Ganoids differ from the Dog-Fish is the possession of an elongated air-containing sac, the swim-bladder or *air-bladder*, which opens into the pharynx, usually on the upper side. In the Bichir, however, the air-bladder, like the lungs of terrestrial Vertebrates, is paired, and opens into the under side of that region. The original use of the swim-bladder is apparently that of a balancing organ, but in some Ganoids (Bichir, Gar-Pike, Bow-Fin) it assists in breathing, and in the Dipnoi has been converted into a lung. It is highly probable that the lungs of the higher Vertebrates are simply to be regarded as modified swim-bladders, and if so, an extremely interesting example of change of function is afforded.

Order 2.—Ordinary Bony Fishes (Teleostei)

Here are included the ordinary bony fishes of the present day, which include some three thousand existing species. The most important features of the group may be understood by briefly describing an average form, such as the common fresh-water Perch, and noting the differences between it and the Dog-Fish (see pp. 257–264).

The Common Perch (*Perca fluviatilis*) (fig. 163) is widely distributed through the fresh waters of Europe and North Asia, and is very beautifully coloured. The upper parts are of a warm reddish-brown, passing into golden on the sides and again into white below. Several broad dark bands run across the body, tapering off on the sides. Well-grown specimens in this country attain a length of 9 or 10 inches, or even a foot, but much larger specimens have been recorded.

The body is much flattened from side to side and the outline is spindle-shaped. It has been compared to a rounded wedge, eminently adapted for rapid progression through the water by

means of the powerful lateral strokes of the large tail-fin, while the remaining fins act as balancers and steerers. The fairly large mouth, its jaws supported by bones bearing small teeth, is placed at the end of the pointed head, and above it may be seen two external nostrils, one on either side of the snout. Farther back still come the large, round, expressionless eyes,

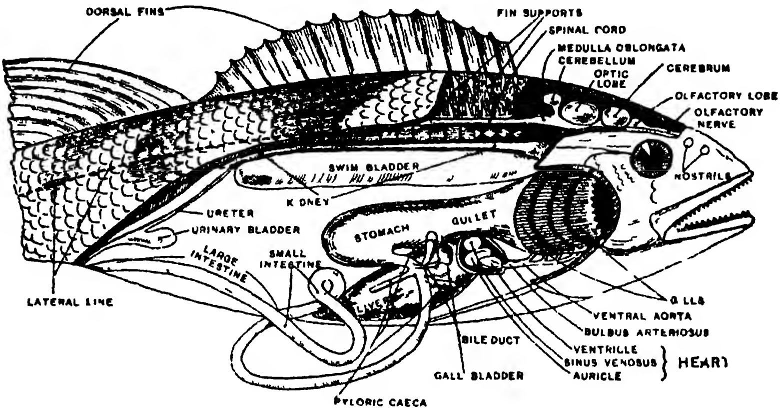


Fig 163 Side dissection of Perch (*Perca fluviatilis*)

devoid of eyelids, but there are no spiracles behind them No gill-slits are externally visible, but these may be seen by lifting up the firm gill-cover or *operculum* placed at the side of the head as in a Ganoid. Four such slits are present, instead of five as in the Dog-Fish (see p 258), with four narrow bar like gill-arches bearing the red, comb-like gills the separate teeth of the combs being the gill-filaments The gill openings here are really slit-like, and not pouches as in Dog-Fish, and their existence is practically demonstrated by every school-boy who strings his small catches on a piece of grass, which he threads through the mouth and gill-slits under the gill cover to the exterior. It is further of great interest to notice that on the inner side of the gill-cover, close to the first gill-slit, there is a small reddish projection. This *false gill* (pseudobranch) is the vestige of the first gill present in a Dog-Fish, and must not be confused with the false gill of that animal (see p. 263), which is on the front wall of the spiracular cleft, here entirely absent.

The *unpaired fins* consist of two large dorsals, of which the

first is supported by exceedingly sharp spines, of an externally symmetrical (homocercal) caudal fin shaped like a fan, and an anal fin, quite close to which is the external opening of the intestine, for there is here no cloaca. Fan-shaped *pectoral* and *pelvic fins* are present, of the rayed type found in living Ganoids except the Bichir and Reed-Fish, and it may be noted that the latter are placed very far forward, much more so than in many other Teleosts. The *lateral line*, marking the position of important sense organs (see p. 263), is indicated by a dark streak running along either side of the body about the level of the eye. The body is covered by thin overlapping scales.

The *internal skeleton* is complicated by the presence of a large number of bones, and contrasts strongly with the comparatively simple cartilaginous skeleton in Dog-Fish (see p. 259). The *skull* is particularly elaborate, and it must suffice to mention once more the presence of tooth-bearing bones bordering the jaws, which are attached at the back to the main skull by a hyo-mandibular bone equivalent to the cartilage of the same name in Dog-Fish (see p. 260). And as the Dog-Fish possesses no operculum, it has nothing corresponding to the bones which support that structure here.

The skeleton by which the base of the tail is supported presents some points of great interest. It will be remembered that in the Dog-Fish the tail is unsymmetrical (heterocercal), the vertebral column bending upwards and running into its upper lobe. Here, on the contrary, the expanded tail is externally symmetrical (homocercal), and the backbone apparently stops short at its base. Examination of certain very young Teleosts, however, shows that in them the tail is unsymmetrical, the backbone bending up in the characteristic way, and close examination of the apparently symmetrical tail of the adult shows that behind the last joint of the backbone is a little bony rod which turns upwards, and marks what is really the posterior end of the body. The homocercal tail, therefore, is really a modification of the old-fashioned heterocercal one, and may be looked upon as an improved type which has arisen from it.

Digestive Organs (fig. 103).—Small pointed teeth are present on the roof of the mouth-cavity as well as on the margins of the jaws, and the usual regions of the gut are present, *i.e.* mouth-cavity itself, pharynx out of which the gill-slits open,

gullet, stomach, and intestine, the last not opening into a cloaca as in Dog-Fish, nor provided with a spiral valve (see p. 261). A large liver is present, but the pancreas appears to be represented physiologically by some blindly-ending tubes (*pyloric cæca*) which open into the beginning of the small intestine.

The *Circulatory Organs*, broadly speaking, are constructed on the same type as in Dog-Fish (see p. 261), though important differences are seen in the *heart*, which no longer possesses an arterial cone with numerous rows of valves, but presents a new structure, the arterial bulb (fig. 163), which succeeds the ventricle, and is really the swollen beginning of the ventral aorta, which, as before, runs forwards on the floor of the gill region, and gives off the afferent branchial arteries that carry the impure blood to the gills to be purified.

The only *organs of respiration* are the gills, of which enough has been said to give an idea of their arrangement

Nervous System and Sense Organs (fig. 163). The *brain* presents the same regions as in a Dog-Fish (see p. 263), but is shorter and broader. The olfactory lobes are not placed on stalks, and there are two cerebral hemispheres instead of an unpaired projection, while the cerebellum is smooth and tongue-shaped.

Two obvious points as regards the *sense-organs* may be mentioned. One is that the nasal sacs have no internal openings into the mouth-cavity as in Dipnoi, but are distinguished by the possession of double external nostrils; while the other peculiarity is a negative one and consists in the absence of the numerous jelly-tubes so characteristic of the Dog-Fish (see p. 263).

A membranous *swim-bladder* (fig. 163) is present, situated above the other internal organs, close to the under surface of the backbone, but though it contains air, it has lost in the adult all connection with the gullet, and therefore cannot play even a subsidiary part in respiration.

Little more can be done here than briefly mention some of the more important or interesting types of bony fishes, but even so, it will make things clearer to indicate the chief groups, which are as follows:—

A.—Teleosts in which the swim-bladder when present has lost its connection with the gullet.

Sub-order 1.—Spine-finned Fishes (Acanthopterygii).
Sub-order 2.—Tuft-gilled Fishes (Lophobranchii).
Sub-order 3.—Firm-jawed Fishes (Plectognathi).
Sub-order 4.—Soft-finned Fishes (Anacanthini).

B.—Teleosts in which the swim-bladder retains its connection with the gullet by a pneumatic duct or tube.

Sub-order 5.—Tube-bladdered Fishes (Physostomi).

Sub-order 1.—SPINE-FINNED FISHES (Acanthopterygii)

Here as in the Perch, which is a type of the sub-order, some or all of the fin-rays which support the dorsal, anal, and pelvic fins are sharp unjointed spines. Some 3650 different species are here included, divided into about 60 families, of which only a few can be mentioned.

1. *Perch Family* (fig. 163).—This is a group of carnivorous fishes, almost entirely confined to fresh water and distributed through the northern hemisphere.

2. *Bass Family.*—This is a large group of fishes, which are for the most part marine though some inhabit fresh water, and which have a very wide distribution. A well-known British species is the Common Bass (*Morone labrax*), which is much like the Perch, but more slender in build and not so brilliantly coloured, being bluish-grey above, gradually shading off to white on the under surface.

3. *Sword-Fish Family.*—The members of this family are large fishes, mostly found in the open sea, and deriving their name from the formidable sword-like weapon into which the upper jaw is produced. The Common Sword-Fish (*Xiphias gladius*) is sometimes taken in British seas, and occurs on both sides of the Atlantic. Other species are found in the Atlantic and Pacific. These fishes have become notorious from the fact that their swords have been found broken off in the timbers of ships, penetrating to a depth of as much as 22 inches (in a specimen exhibited in the British Museum). The force with which such blows have been given may be imagined.

4. *Dory Family.*—This includes marine fishes of extraordinary form, found in the East Atlantic, Mediterranean, and the seas of Australia and New Zealand. The John Dory (*Zeus faber*) is not uncommonly found in British seas. The body is much flattened, and with the head has a broad oval outline.

From behind each of the sharp spines of the large first dorsal fin projects a long filament. A small part of the upper side is dark-brown, which shades into golden-yellow farther down, and again into brownish white. On each side of the body there is a large round blotch, dark in colour with a lighter margin. By the ancient Romans it was regarded as sacred to Neptune.

5. *Mackerel Family.*—This is an important group of carnivorous food-fishes, abundant in the temperate and tropical seas of both hemispheres. They are remarkable for their powers of swimming. The Common Mackerel (*Scomber vernalis*) suggests the lines of a racing-boat in the beautifully graduated curves of its rather slender body, terminated behind by a well-developed caudal fin shaped like the head of a broad arrow. Rows of pointed finlets fringe the body in the spaces between the tail and the anal and second dorsal fins.

Another member of the family, sometimes taken off the south of England, and the object of an important Mediterranean fishery, is the Tunny (*Orcynus thynnus*), which may attain the length of 10 feet and a weight of more than 1000 pounds. Smaller species of the same genus are the Bonito (*Thynnus pelamys*) and Albicore (*Thynnus albicora*), which prey largely on Flying-Fishes, and, being rendered conspicuous by this habit, are often mentioned in accounts of voyages.

6. *Angler-Fish Family.*—This embraces widely-distributed fishes of extraordinary form, some of which frequent shallow water, while others drift with sea-weed in the open ocean, and still others live at great depths. A well-known British species is the Fishing-Frog (*Lophius piscatorius*), with its body dwarfed by an enormous head, the wide gaping mouth of which, armed with numerous teeth, is a regular death-trap for unwary little fishes of all sorts. The first dorsal is reduced to its long spines, the foremost of which terminates in a soft flap. The upper side is of a blackish brown and the under side white.

7. *Bull-Head Family.*—These are small ground fishes of wide distribution, and mostly found near to land, while there are also fresh-water forms. A common British species is the Bull-head or Miller's Thumb (*Cottus gobio*), common in brooks, as every school-boy knows; while just as common along our shores is the Sea-Scorpion (*Cottus scorpius*), which has much the same appearance.

8. The *Gurnards* are larger relatives of the preceding and are distinguished by their curiously-shaped bony heads, and by the fact that the first three rays of the pectoral fin have become distinct and form "fingers" used as organs of touch and in progression along the sea-bottom. They are fishes of wide distribution and often of bright coloration. The commonest British species is the Red Gurnard (*Trigla pini*), which is bright red in colour above and gleaming white below and on the sides.

9. *Goby Family.*—Gobies and their allies are small fishes common along the coasts of both tropical and temperate seas, while some are estuarine and a few inhabit fresh water. There are nearly a dozen British species, of which the largest and probably on that account best known is the Rock Goby (*Gobius niger*). In these fishes the pelvic fins are united into a funnel-shaped sucker.

10. *Blenny Family.*—The fishes of this family are mostly small and have the same wide distribution as the Gobies. The pelvic fins are very much reduced, and there is a single dorsal running along the whole length of the back, and equivalent to the two dorsals of perch fused together. A common British species is the Smooth Blenny or Shanny (*Blennius pholis*), in which the long, low dorsal fin is not broken into sections. The Wolf-Fish (*Anarrhichas lupus*), common on the north British coasts and ranging to Norway and Greenland, may be over 6 feet long, and resembles the Shanny on a large scale. The margins of its jaws and the roof of the mouth are studded with blunt teeth, adapted for breaking the coverings of molluscs and crustacea.

11. *Grey Mullet Family.*—Grey Mullets are common along the coasts of tropical and temperate regions, frequenting estuaries. The first dorsal fin is small, with only four spines, and the lateral line is absent. The best known British species is the Common Grey Mullet (*Mugil capito*)

12. *Mackerel-Pike Family.*—Here are included Gar-Fishes and Flying-Fishes. The former are distributed throughout tropical and temperate seas, and the Common Gar-Fish (*Belone vulgaris*) is common on the British coasts. The body is much elongated and the snout is lengthened into a narrow pointed beak, well suited for seizing small fish. *Flying-Fishes* include a considerable number of species limited to the warmer parts of the ocean. The

Common Flying-Fish (*Exocœtus volitans*), found in all tropical seas, has immensely elongated pectoral fins, which constitute the so-called wings.

13. *Stickleback Family.*—The familiar little fishes constituting this family are mainly, but not entirely, inhabitants of fresh water, and are only found in the Arctic and North Temperate zones. The name is derived from the fact that the first dorsal fin is represented only by its spines, of which there are a variable number. There are three common British species, all of them nest-builders. Of these the largest is the Sea Stickleback (*Gastrosteus spinachia*), with fifteen spines. It also frequents brackish water. The other two kinds live in fresh or brackish water, the smaller being the Ten-spined Stickleback (*Gastrosteus pungitius*) or "Tinker", while the other is the Three-spined Stickleback (*Gastrosteus aculeatus*).

14. *Wrasse Family.*—Wrasses are widely-distributed shore fishes, being absent, however, from the polar regions, and are especially numerous on rocky coasts and coral reefs. Most of them are handsomely coloured, and some are pre-eminent among fishes in this respect. The bones which constitute the bases of the skeleton supporting the gill-arches (lower pharyngeal bones) are fused together into a single tooth-bearing piece. Many members of the group are distinguished by the possession of thickened lips, and all have blunt conical teeth suitable for crushing the shells of molluscs and crustacea, of which the food consists. There are a number of British species, of which one of the commonest is the Ballan Wrasse (*Labrus maculatus*), a stoutly-built fish of some 15 inches long. The colour is of a bright brown with numerous whitish spots, and touches of green on the fore-part of the head and the bases of the fins. Some individuals, however, are of a greenish colour all over. The spiny first dorsal is long and low, while the soft second dorsal is much shorter and higher.

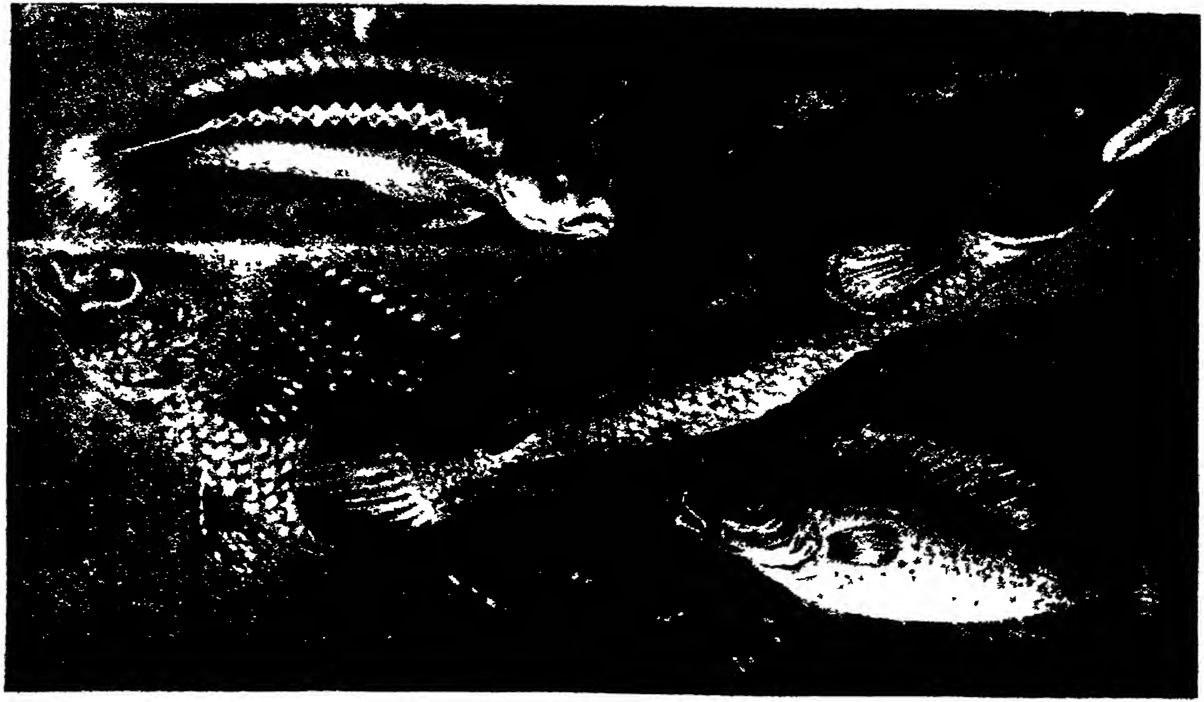
Sub-order 2.—Tuft-gilled Fishes (Lophobranchii)

This small sub-order includes about 120 species of curiously modified fishes, in which pelvic fins usually, and anal and caudal fins commonly, have disappeared. The snout is drawn out into a tube, at the end of which the small rounded toothless mouth

WRASSES (*Labridæ*)

Wrasses are tropical and temperate shore fishes, possessed of thick lips and crushing teeth well suited to the food, which consists of molluscs. Many of them are beautifully coloured. All four of the species figured are native to the seas of Britain. Their names are:—

1. Rainbow Wrasse (*Coris julis*).
2. Ballan Wrasse (*Labrus maculatus*).
3. Cuckoo Wrasse (*L. mixtus*), male.
4. Corkwing (*Crenilabrus melops*).



WRASSES (LABRIDAE)

1 Rainbow Wrasse 2 Ballan Wrasse 3 Cuckoo Wrasse 4 Corkwing.

is situated. Scales are absent, but their place is taken by bony plates developed in the deeper part of the skin and arranged in regular transverse rings. The name of the group (Gk. *lophos*, a tuft; *branchia*, gills) has reference to the gill filaments, which are arranged in tufts and not in combs as in ordinary Teleosts. The male fish usually has a pouch in the skin on the under side of the body in which the eggs are developed and the young protected.

The Great Pipe-Fish (*Syngnathus acus*) is a common British species with much elongated cylindrical body and a small caudal fin. A much more extraordinary looking species is the Short-snouted Sea-Horse (*Hippocampus antiquorum*) (fig. 164), which has a very wide range and is sometimes found off the British coast. The name is suggested by the shape of the head, which is sharply bent on the trunk and separated from it by a sort of neck. The animal maintains a vertical position in the water both when swimming and also when attached to sea-weed by means of its prehensile tail, which is devoid of a caudal fin.

Fig. 164.—Hippocampus.

Sub-order 3.—Firm-jawed Fishes (Plectognathi)

This also is a small group embodying about 180 species, most of which have a well-developed external skeleton. There is as a rule nothing to correspond to the spiny first dorsal and pelvic fins of a perch, except, perhaps, a few spines. The gill-cover is not a large free flap, but is united with the surrounding parts so as to leave only a small aperture through which the water which has passed over the gills can flow out to the exterior. The internal skeleton is deficient in bony matter, but the bones of the upper jaw are very firm and fused to the main mass of the skull, a feature which the name of the sub-order suggests (Gk. *plektos*, woven together; *gnathos*, jaw). The included species are characteristic of tropical seas, though not confined to them, and include: 1. File-Fishes, 2. Coffer-Fishes, 3. Globe-Fishes, and 4. Sun-Fishes.

1. *File-Fishes* constitute a widely distributed family, in which

the skin is rough and there is a small spiny first dorsal fin, of which the first spine is ridged like a file on its front surface. The firm jaws, provided with strong teeth, are well adapted for breaking open the shells of molluscs, or nipping off pieces of coral. The Mediterranean File-Fish (*Balistes capriscus*) has occasionally been taken in British seas.

2. *Coffer-Fishes* are curious-looking creatures in which the body is almost entirely protected by numerous six-sided plates united by their edges. The Four-horned Coffer-Fish (*Ostracion quadricornis*) has been taken off the coast of Cornwall.

3. *Globe-Fishes* mostly have their bodies covered with strong spines, and possess the power of dilating the gullet with air, when the body swells out into a globe-like form and the spines are erected, furnishing a formidable protection. In this condition they are unable to swim, but are drifted along with the under side turned upwards. In the genus *Diodon* there is a bony plate in the front of each jaw, while in the allied genus *Tetrodon* each of these plates is divided into two, giving the appearance of four large front teeth.

4. *Sun-Fishes* are remarkable for the shortness and depth of the body, the caudal fin forming a border to the hinder end, which does not taper as in an ordinary fish. Adjoining the caudal fin is a long pointed dorsal above and a similar anal below.

Sub-order 4.—Soft-finned Fishes (Anacanthini)

In these fishes the rays which support the various fins are all soft and jointed, and the pelvic fins are situated very far forwards. There are some 370 species, of which many are of great economic importance. Only two of the included families need be mentioned here, *i.e.*: 1. the Cod Family, and 2. that in which the Flat-Fishes are included.

1. *Cod Family.*—The Common Cod (*Gadus morrhua*) (fig. 1) is the most important representative of a genus distinguished by the possession of three dorsal and two anal fins, while in this and some of the other species of the genus there is a filament or barbel attached to the lower jaw. The Cod abounds on both sides of the northern part of the North Atlantic, the most famous fishery being on the banks of Newfoundland. The Haddock (*Gadus æglefinus*) is another important species with a

similar range. It can easily be distinguished from the Cod by the black colour of the lateral line, and the presence of a rounded black patch just behind the gill cover. A third allied but smaller species is the Whiting (*Gadus merlangus*), the range of which is restricted to the seas of Northern Europe. It has a dark patch at the root of each pectoral fin and lacks the barbel of the two preceding species.

A small number of the species included in the Cod Family are fresh-water, and the best known of these is the Burbot or Eel-pout (*Lota vulgaris*), abundant in many of the rivers of North America and North and Central Europe. In England it is found in some of the rivers which flow into the North Sea. There are two dorsal fins, of which the second is very long and low, while on the under side of the body there is an anal fin of similar character. A barbel is present as in the Cod.

2. *Flat-Fish Family.*—The familiar food-fishes which make up this family are distinguished by a remarkable want of symmetry, which has no parallel among Vertebrates. One might at first sight imagine that the dark and light surfaces of the body were respectively upper and lower. A little closer inspection, however, would show that a long dorsal fin ran along one edge of the body and a long anal fin along the other; and further, that each surface had a lateral line running along it, and possessed both gill-cover and paired fins, thus conclusively proving the broad surfaces to be the sides. In some cases the dark upper side is the right one and in others the left. A flat-fish starts life with the same kind of symmetry as an ordinary fish, one eye being on the right and the other on the left, while the body is maintained in the usual position; but as development proceeds, and the body gets more flattened, one side becomes pigmented, and the eye of the contrary side is displaced so as to be near its fellow. We may take as well-known examples, Turbot, Plaice, and Sole.

The Turbot (*Rhombus maximus*) (fig. 34) is a large broad fish limited to European seas, and with the eyes on the *left* side. In the Plaice (*Pleuronectes platessa*), which though broad is a much smaller fish, the dark, eye-bearing surface is the *right* side. It is marked by large orange spots. This species ranges along the west coast of Europe and extends as far north as Iceland. The Common Sole (*Solea vulgaris*) also has the eyes

on the *right* side, but its shape is an elongated oval. It is confined to European seas.

Sub order 5.—TUBE-BLADDERED FISHES (Physostomi)

This large group (some 2500 species) includes many important food fishes, and includes both marine and fresh-water forms, as well as forms which, like the Salmon, live partly in the one and partly in the other. The fins are supported by soft jointed rays, except in some cases the first ray in the dorsal and pectoral, which may be transformed into spines. The pelvic fins are situated far back in what must be considered as the primitive position, judging by other orders of fishes. The air-bladder, which, as previously stated, is an outgrowth from the gut, always retains a connection with it by means of a tube, whence the name of the sub-order. Only the more important families can be mentioned here.

1. *Cat-fish Family.*—The Cat-Fishes or Siluroids include a large number of species inhabiting the fresh waters of tropical and temperate regions, while some of them are estuarine or even marine, though in the latter case they do not go far from shore. The name Cat-Fish has reference to the presence of long barbels, suggesting to a lively imagination the whiskers of a cat. The scaleless body is sometimes protected by bony plates. There is only one European species, the Wels (*Silurus glanis*) (fig. 165), and this is limited to the rivers east of the Rhine. Excepting only the Giant Sturgeon, it is the largest of European fresh-water fishes, attaining a maximum length of 13 feet and weight of 400 pounds, though average specimens are very much smaller. In this species the skin is soft, and there are six barbels, two very long ones above and four much smaller ones below.

2. *Salmon Family.*—The members of this group are in the main either purely fresh-water in habit or ascend rivers to spawn, and, with the exception of a New Zealand genus, are confined to the northern hemisphere. There are, however, a few purely marine species. The body is of the typical fish form, and covered with scales, except in the head region. A fairly-large first dorsal is situated about the middle of the back, and much farther back there is a small second dorsal, which, on

Fig 165 Group of Fishes reduced to various scales.

1 Salmon (*Salmo salar*) 2 Common Sturgeon (*Acipenser sturio*) 3 Wels (*Silurus glanis*) 4 Eel [illegible]

account of its fatty texture, is generally called the adipose fin. An anal fin is placed opposite or nearly opposite this.

The Salmon (*Salmo salar*) (fig. 165) ranges right round the northern hemisphere as far south as latitude 41° in the New World and 43° in the old. It is well known as one of the fishes that live partly in the sea and partly in fresh water, while the Common Trout (*Salmo fario*) is limited to the latter.

The Common Smelt (*Osmerus eperlanus*) is an example of the smaller members of the Salmon family. It is found in the seas of both Northern and Central Europe, as well as in some of the lakes and rivers of the same regions.

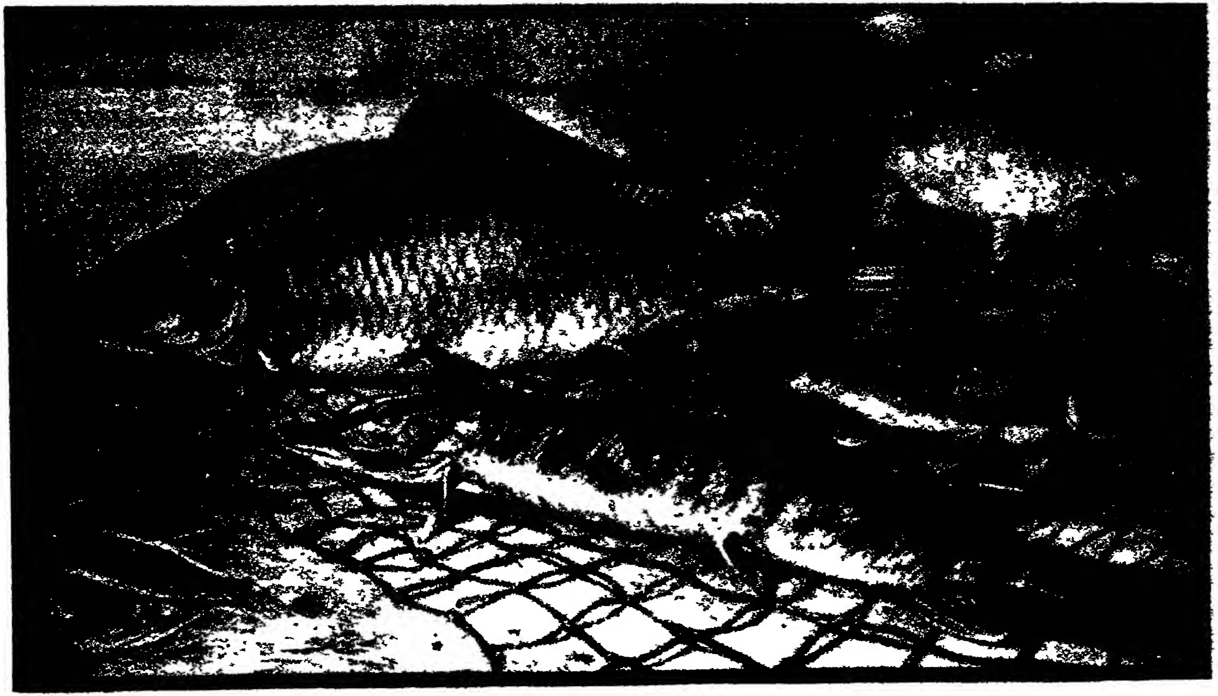
3. *Pike Family*.—This is a small group of predatory fresh-water fishes, including only seven species, of which six are confined to the United States, while the Common Pike (*Esox lucius*) has a wide distribution through the temperate regions of the northern hemisphere. There is no fatty fin, and the single dorsal is placed far back near the tail. The shape of the head, with its flattened snout and projecting lower jaw, is very characteristic.

4. *Carp Family*.—This is a large group of fresh-water fishes distributed through all the great land masses except South America and Australia. There is no fatty fin, and the mouth is entirely devoid of teeth, though these structures are present in the pharynx, attached to the bones which support the gill-arches. The Common Carp (*Cyprinus carpio*) is a stoutly-built fish with a long dorsal fin and two pairs of small barbels. It is a native of Asia, but, being much esteemed as food, was introduced into Europe at an early date, and is supposed to have been naturalized in this country by the monks during the Middle Ages. The well-known Gold-Fish (*Carassius auratus*) is a domesticated species of a genus of carps in which barbels are absent. It is a native of China and Japan, and the bright colouring is the result of artificial surroundings. Remarkable varieties of form have also been produced, as in other animals which have come under the influence of man.

Among native members of the family may be mentioned the Gudgeon (*Gobio fluviatilis*), a small fish with a pair of short barbels; the much larger Barbel (*Barbus vulgaris*), with four barbels; the Common Bream (*Abramis brama*); the Bleak (*Alburnus lucidus*), Roach (*Leuciscus rutilus*), Chubb (*L.*

GROUP OF FRESHWATER FISH

1. The Carp (*Cyprinus carpio*) inhabits ponds, lakes, and sluggish streams, living upon worms, insect larvæ, &c., and vegetable matter, to which food its thick-lipped mouth, provided with four sensitive barbels, is well adapted. It is very tenacious of life, and exceedingly long-lived (100 years or more). 2. The Crucian Carp (*Carassius vulgaris*) is a small fish common in the lakes and ponds of Central and Northern Europe. It is often kept in captivity, together with its near relative, the Gold-Fish, which is a domesticated variety of the Golden Carp (*C. auratus*). 3. The Tench (*Tinca vulgaris*) is a well-known ground-fish of the carp kind, and its food is of the same mixed nature. It lives in stagnant water, which may be so foul that no other fishes can maintain themselves in it. 4. The Pike (*Esox lucius*) is an exceedingly voracious fish, widely distributed through temperate North America, Europe, and Asia. It attains a very considerable size.



GROUP OF FRESHWATER FISH

1 The Carp (Cyprinus carpio)
2 The Crucian Carp (Carassius vulgaris).
3 The Tench (Tinca vulgaris)
4 The Pike (Esox lucius)

cephalus), Dace (*L. vulgaris*), and Minnow (*L. phoxinus*); Tench (*Tinca vulgaris*); and the Common Loach (*Nemachilus barbatulus*), a small elongated slimy fish, with mouth on the under side of the head and a fringe of six barbels round the edge of the upper jaw.

5. *Herring Family.*—The fishes of this family are mostly marine, and are found in the shallower parts of the sea all the world over in tropical and temperate regions. Although not distinguished by number of species, they are unsurpassed among fishes in the number of individuals, these often swimming together in vast shoals, which partly accounts for their very great commercial value. The body is of the typical fish-shape, and much laterally flattened, especially on the under side, which may form a sharp edge, often with a saw-like margin and sometimes supported by small bony plates. Fatty fin and barbels are absent. The head is naked, but the rest of the body is covered by thin glittering scales, which are easily detached.

The Herring (*Clupea harengus*) abounds in the North Atlantic, North Sea, and Baltic, and is also found in the Black Sea. The Pilchard (*C. pilchardus*) ranges from the Mediterranean round to the English Channel, and when young is the familiar Sardine. The Sprat (*C. sprattus*) abounds on the west coast of Europe and extends into the Baltic and part of the Mediterranean.

6. *Eel Family.*—The snake-shaped fishes belonging to this family have a wide distribution through both the seas and fresh waters of tropical and temperate regions. The pelvic and sometimes the pectoral fins also are absent, and the dorsal, caudal, and anal fins all form a continuous fringe. The skin is either entirely devoid of scales, or numerous very minute scales are imbedded in it.

The Common Eel (*Anguilla vulgaris*) (fig. 165) has pectoral fins and minute scales. It has a wide distribution throughout Europe, the countries bordering the Mediterranean, and North America. The large marine eel known as the Conger (*Conger vulgaris*) is found in almost all parts of the world, and is distinguished from the Common Eel by the entire absence of scales, and its large mouth armed with formidable teeth. The maximum length appears to be about 8 feet. The Mediterranean Muræna (*Muræna helena*) is the typical representative of a widely-distri-

buted section of marine eels. It attains the size of the Conger and was well known to the ancient Romans, who not only esteemed it as a delicacy but kept it as a pet. The skin is scaleless, as in the Conger, and is brilliantly coloured. The front end of the body is very thick, and the large mouth is armed with powerful teeth. Pectoral fins are entirely absent.

Sub-class III.—SHARKS AND RAYS (Elasmobranchii)

The Spotted Dog-Fish (*Scyllium canicula*) is a good type of this sub-class, and the description already given of it (pp. 257–264) will serve to give an idea of the essential features in the structure of the group. The most important of those features are the following:—The unsymmetrical tail, and position of the mouth and nasal openings on the under surface of the head. The possession of spiracular clefts and at least five pairs of gill-pouches, the external openings of which are not protected by a gill-cover. A cartilaginous skeleton, with comparatively simple skull and well-developed visceral skeleton, and paired-fin skeleton on the Dog-Fish type. Numerous rows of teeth on the margins of the jaws, constantly being renewed during life. A spiral valve in the intestine, and a cloaca. Well-developed arterial cone in the heart. A thick skin with placoid scales. No swim-bladder, or at most a small tubular outgrowth from the upper side of the gullet to represent it. Eggs large, containing much food-yolk.

It is convenient to divide these fishes into two orders, one containing the Sharks and Dog-Fishes (Selachoidei), the other Skates and Rays (Batoidei).

Order 1.—Sharks and Dog-Fishes (Selachoidei) (fig. 166)

The shark-like fishes of this order comprise about 150 species, distinguished by spindle-shaped bodies gradually tapering to the tail-end, which is sharply bent up. The gill-slits open on the side of the body, and the eyes possess lids. There are nine families, of which only seven need be mentioned.

1. *Blue Sharks.*—The type of this family is the Blue Shark (*Carcharias glaucus*), which often reaches the length of 15 feet. Though not uncommon in British seas during the warmer part of the year they are specially abundant in the tropics, like most

of the larger sharks. The Common Tope (*Galeus canis*) is a small shark with a very wide distribution, and is a well-known British species. It may attain a length of 6 feet or more, and in colour is dark grey above and white below. The body is slender and the snout prolonged and pointed. A somewhat

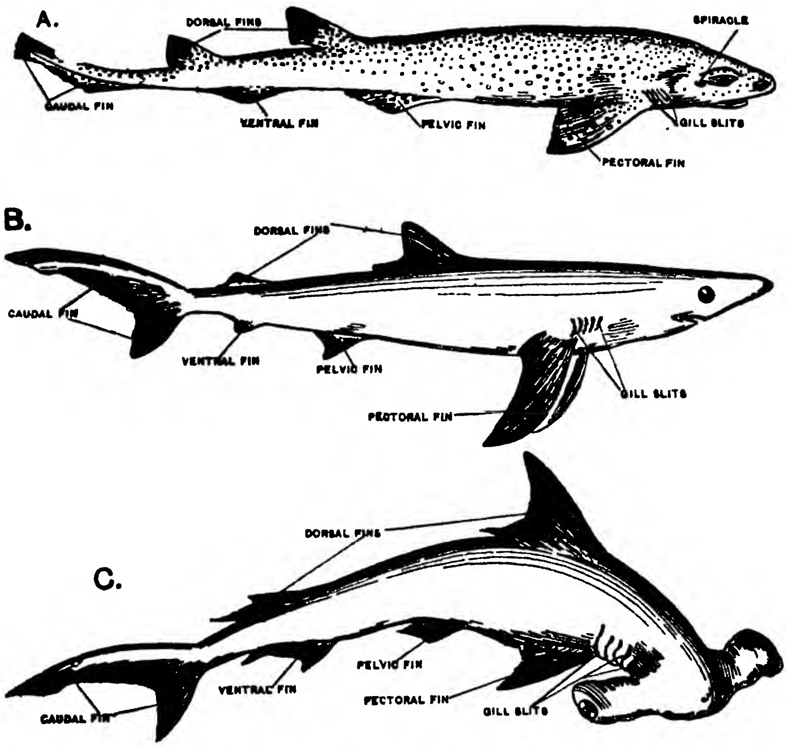


Fig. 166.—Sharks, reduced to various scales

A, Spotted Dog-Fish (*Scyllium canicula*). B, Blue Shark (*Carcharias glaucus*).
C, Hammer-headed Shark (*Zygæna malleus*).

smaller form, common in British seas and widely distributed over the world, is the Smooth Hound (*Mustelus lævis*), which can easily be distinguished from the Tope by its blunter snout, and the presence of whitish spots on the back. The most remarkable-looking member of this family is undoubtedly the Hammer-headed Shark (*Zygæna malleus*), in which, as the name indicates, the head is broadened out like a T by the presence of projections upon which the eyes are situated. It has occasionally been taken in

British seas, but cannot be considered as a native species, its habitat being the warmer parts of the ocean in almost all parts of the world.

2. *Porbeagles.*—This includes sharks, which are most abundant in the open ocean and are often of very large size. The pointed teeth are large and strong, and the gill-slits are usually very wide, while the spiracle is small or even absent. The Porbeagle (*Lamna cornubica*) is a North Atlantic form and fairly common on British coasts. It is about 10 feet long. The Thresher or Fox-Shark (*Alopecias vulpes*) is distinguished by the remarkable length of the upper lobe of the tail. It is abundant in the Atlantic and is the commonest large shark occurring on our coasts, but is also well-known in the Mediterranean, its range also including the coasts of California and New Zealand. The Basking-Shark (*Selache maxima*) of the North Atlantic may reach a length of over 30 feet. It is not uncommon on our western coasts. Unlike the last-named species, which does not attack man, the huge Rondeletian Shark (*Carcharodon Rondeletii*), which may attain the length of 40 feet, is universally dreaded. It is found in the warmer parts of the open sea in all parts of the world.

3. *Dog-Fishes.*—Of this the Spotted Dog-Fish, selected as our type (pp. 257–264), is a typical member. All are coast-fishes, found in most tropical and temperate seas. Another British species, closely resembling the preceding but of much larger size, is the Nurse Hound (*Scyllium catulus*). The Zebra Shark (*Stegostoma tigrinum*), common in the Indian Ocean, is a member of this family. It may be as much as 15 feet long, and receives its name from the characters of its markings, which consist of dark transverse bands on a yellowish ground.

4. *Spiny Dog-Fishes.*—The species belonging here are mostly of small size and are devoid of an anal fin. The gill-slits are small and a spiracle is present. The Piked Dog-Fish (*Acanthias vulgaris*) is common on the British coasts, and is characterized by the presence of a sharp spine in front of each dorsal fin. A much larger species is the Greenland Shark (*Læmargus borealis*), which inhabits the seas of the Arctic region, and is one of the worst enemies of the Greenland Whale, from the tail of which it bites large pieces. It sometimes strays as far south as Britain, and, though it may be as much as 15 feet long, is harmless to man.

5. *Angel-Fishes.*—This contains a single species, the Angel- or

Monk-Fish (*Rhina squatina*), found all over the world in tropical and temperate seas, and not uncommon on our western coasts. Its chief interest lies in its flattened shape, in which respect it may be regarded as an intermediate stage between the sharks and skates, and in the extremely large pectoral fins (the "wings" of the imaginary angel) which also afford a point of resemblance to the latter group.

6. *Port Jackson Shark Family.*—This is a small group of comparatively small forms, including only one genus of four species, of which two are found on either side of the Pacific. The best known is the Port Jackson Shark (*Cestracion Philippi*) which ranges from Japan south to Australia and New Zealand. The head is short and blunt, and there is a sharp spine in front of each dorsal fin; but the chief peculiarity is found in the teeth. Those in front are sharp-pointed, but the rest have blunt rounded crowns, and, being arranged in several closely adjacent rows, form a surface well adapted to crush the molluscs upon which the shark feeds.

7. *Comb-toothed Sharks.*— This is a small group of tropical and sub-tropical species possessing certain primitive characters. There is only one dorsal fin, and the gill-slits, instead of being five in number on each side, as in other members of the sub-class, are either six or seven. Four of the five known species belong to one genus (*Notidanus*), and one of them, the Grey Six-gilled Shark (*N. griseus*), an Atlantic and Mediterranean form, is sometimes taken in British waters. The teeth are elongated, and each of them consists of a series of slanting cusps diminishing in size from one end of the tooth to the other. The other three species of this genus have seven gill-slits on each side. The Japanese Frill-gilled Shark (*Chlamydoselache anguineus*), which inhabits very deep water, resembles an eel in shape, and its mouth is at the front end of the body instead of upon its under surface. There are six gill-slits on either side, and each of them is protected by a backwardly-directed fold of skin, pleated in a frill-like manner.

Order 2.—Skates and Rays (Batoidei) (fig. 167)

The Skates and Rays which constitute this group are much flattened from above downwards, just the reverse of what obtains

in an ordinary flat-fish, the breadth being increased by the enormous development of the pectoral fins, which form great wings extending from the head to the pelvic fins. As a result of this depressed shape, the gill-slits, of which the typical five pairs are present, are situated on the under side. The tail is narrow and forms a mere appendage, upon the upper side of which the small dorsal fins are placed, while the anal fin is absent. There are six families, of which five may be specially mentioned

1. *True Rays*.—The numerous species of the rhomboidal-shaped fishes belonging to this family have a wide distribution, but are chiefly temperate forms more abundant in the northern than in the southern hemisphere. The numerous small teeth are closely packed in a considerable number of rows arranged so as to form two roller-like surfaces which bite against one another. There are about twelve British species, of which the commonest are the Skate (*Raia batis*), in which the skin is comparatively smooth, and the Thornback (*Raia clavata*), which has the dorsal surface irregularly studded with large placoid scales of curious shape, each consisting of a circular disc from which a thorn-like spine projects, while a row of similar scales runs down the middle of the back.

2. *Saw-Fishes*.—This [illegible] species of [illegible] generally characteristic of tropical [illegible] one of [illegible] (*Pristis antiquorum*) [illegible] common [illegible] Mediterranean. The body is not broadened [illegible] and in this respect is so [illegible] the Sharks. A remarkable peculiarity [illegible] the prolongation of the snout into a long [illegible] of which are imbedded sharp teeth [illegible] feet in length [illegible] as much as six of [illegible] taken up by the saw.

3. *Eagle-Rays*.—These [illegible] tropical and temperate zones, one species, the Eagle Ray (*Myliobatis aquila*) being occasionally taken in British seas. The extremely slender tail is armed above with a strong spine, while the teeth, instead of being pointed, have flattened crowns, and are in contact with one another at the edges so as to constitute a very perfect crushing surface, shaped like a roller.

4. *Sting-Rays*.—This group includes much modified Rays, commonest in the tropics. The body is excessively broad and the pectoral fins run forwards so as to surround the front of the

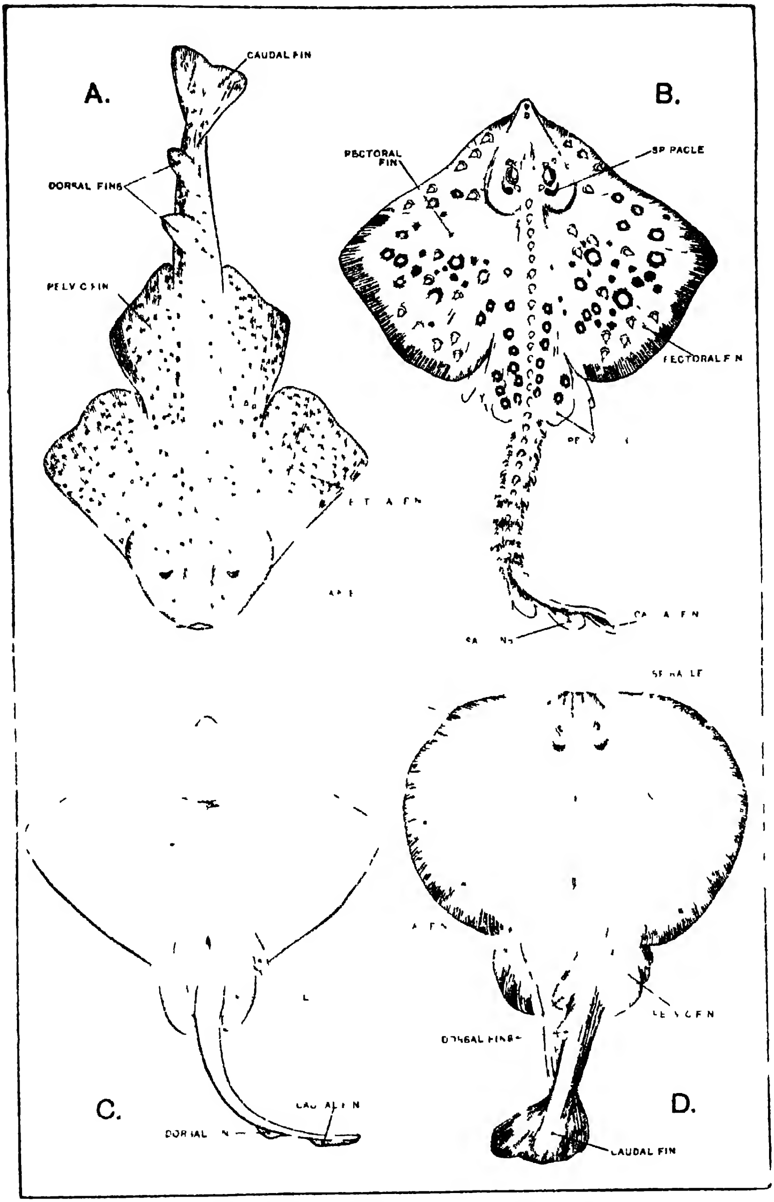


Fig. 167.—Monk Fish and Rays, reduced to various scales

A, Monk Fish (*Rhina squatina*); B, Thornback (*Raia clavata*); C, Under Side of young Skate (*Raia batis*); D, Electric Ray (*Torpedo nobiliana*).

head. The slender tail is usually armed with a formidable saw-edged spine, which is the so-called "sting". One widely distributed species, the Common Sting-Ray (*Trygon pastinaca*), is sometimes caught off the south of England.

5. *Electric Rays.*—In these the broad smooth body has a rounded outline, and on each side of the head there is an electric organ, capable of giving severe shocks. The most familiar genus, Torpedo, is represented by species in the Atlantic, Mediterranean, and Indian Oceans. A well-known Mediterranean form is the Marbled Torpedo (*Torpedo marmorata*), and an allied species is taken from time to time in British seas.

Sub-class IV.—CHIMÆRAS (Holocephali) (fig. 168)

This small sub-class, though related in many ways to the preceding one, is distinguished by a number of peculiarities. It includes only three genera of deep-water fishes. The best-

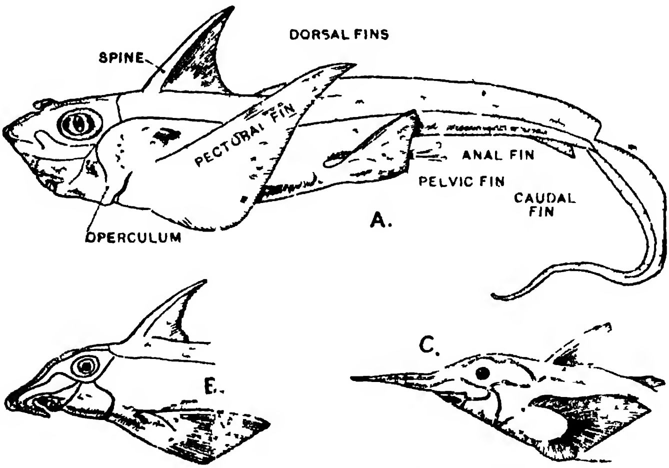


Fig. 168.—Chimæroids, reduced to various scales
A, Sea Cat (*Chimæra monstrosa*), male. B, Bottle-nosed Chimæra (*Callorhynchus antarcticus*). C, *Harriotta*.

known form is the Sea-Cat or "King of the Herrings" (*Chimæra monstrosa*), the distribution of which includes the North Atlantic, Mediterranean, Cape of Good Hope, and Japan. In this animal the large head is rounded and the tail tapers to a mere thread. There is a powerful spine in front of the first dorsal fin, while in the male there is a peculiar tentacle-like

structure on the top of the head, armed with curved spines and capable of being drawn back into a pit. The eyes are very large and the skin is smooth. Only four gill-slits are present on each side, and they are covered over by a membranous flap or gill-cover. There is no spiracle. Another species of Chimæra is taken off the coast of Portugal, and the third is found on the Pacific coast of North America.

The Bottle-nosed Chimæra (*Callorhynchus antarcticus*) of the southern seas is more shark-like in form, and its name is derived from the curious thickened form of the snout. A third genus (*Harriotta*), recently discovered in very deep water both in the Atlantic and Pacific, is comparatively small and is distinguished by its slender-pointed snout.

SUB-CLASS V.—ROUND-MOUTHS (CYCLOSTOMATA)

The Lampreys and Hags which make up this sub-class are so unlike other fishes in many respects that many zoologists place them in a class of their own. They have a wide distribution

Fig. 169.—Lampern (*Petromyzon fluviatilis*).

in the temperate regions of both hemispheres, and the lampreys occur in fresh as well as in salt water. There are four British species, three of these being lampreys, any one of which will serve to illustrate the chief characters of the sub-class. They are the Sea-Lamprey (*Petromyzon marinus*), the River-Lamprey or Lampern (*P. fluviatilis*) (fig. 169), and the Small Lamprey (*P. branchialis*). The eel-like body is bordered by three narrow unpaired fins, two dorsals and a caudal, but all traces of paired fins are absent. Instead of possessing a slit-like mouth bounded by jaws, as in all the backboned forms so far considered, a rounded sucker-like concavity is present on the under surface of the head, and the small mouth opens within this. The scientific

name of the group is derived from this peculiarity (Gk. *kuklos*, a circle; *stoma*, a mouth). The skin is devoid of scales, but there are numerous little horny structures lining the mouth-sucker, and a muscular tongue armed with similar bodies can be protruded from the mouth and used as a rasping organ. A single nostril opens on the top of the head, behind this is the eye, and then come seven small round holes, which are the external openings of as many gill-pouches. The egg of the Lamprey develops into a larva which is so unlike the adult that it was formerly thought to be a distinct kind of fish and received the name of *Ammocœtes*.

The Common Hag-Fish (*Myxine glutinosa*) is shaped like a Lamprey, but the dorsal fin is absent, and the imperfect eyes are covered by the skin. The suctorial mouth is margined by eight barbels. At first sight there appear to be no gill openings, but there are in reality six pairs of gill-pouches, the outer ends of which are drawn out below the skin into backwardly directed tubes, those on the same side uniting together and having a common opening pretty far back on the under surface of the body. The skin is very glandular, possessing the power of producing vast quantities of slime which sets into a firm jelly

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PRIMITIVE VERTEBRATES (PROTOCHORDATA)

We now come to a number of very primitive forms, most of which were classified with the backboneless animals till comparatively recently. The characters of the backboned animals or Vertebrates have been enumerated and explained in an earlier part of this volume (pp. 60 63), to which reference must be made for details. It may, however, be remarked here that there are three chief characters by which a Vertebrate, or, to use a wider and better term, a Chordate, may be distinguished.

1. The possession at some period of life of a firm gelatinous rod, the *notochord*, running longitudinally below the central nervous system. Such a supporting rod can be made out in the embryos of all the forms hitherto described, but in most of them it is sooner or later squeezed out of existence, partly or entirely, by the development of a vertebral column. In some few instances,

however, as Lung-Fishes, Chimæra, Lamprey, and Hag, it persists throughout life, though invested in a firm sheath and supplemented by the development of cartilage. Ordinary bony fishes are a good instance of partial persistence of the notochord. Almost everyone must have noticed, in the pursuit of breakfast-table anatomy, that a gelatinous substance occupies the spaces between the doubly-cupped ends of the vertebræ in such fish as salmon and cod. This substance represents the part of the notochord which has not been nipped out of existence by the ingrowth of hard material to make up the joints of the backbone. In a Protochordate there never is a vertebral column or a backbone in the proper sense of the word, but only a more or less developed notochord.

2. It is scarcely less distinctive of Chordate animals that in them the pharynx should be perforated by visceral clefts in the embryo if not in the adult.

3. It is typical for a Chordate to possess a central nervous system (brain and spinal cord) situated *dorsally* above the notochord, and having the nature of a thick walled *tube*.

We will apply these tests to the three recognized orders of Protochordates, *i.e.*: 1. Lancelets (Cephalochorda), 2. Sea-Squirts (Urochorda), and 3. certain still simpler forms grouped provisionally as Hemichorda. Very great theoretical interest attaches to the study of these forms, and much attention has been bestowed upon them, largely with a view of finding out how far they throw light upon the obscure problem having for its goal a determination of the characters of the simplest and earliest Vertebrates which appeared upon the globe.

SUB-CLASS I. - LANCELETS (CEPHALOCHORDA)

Lancelets are small fish-like creatures widely distributed round the coasts of the globe where the two conditions of sand and shallow water are combined. There are about 8 species, popularly referred to one genus *Amphioxus* (Gk. *amphi*, both; *oxus*, sharp), which, like the ordinary name, has reference to the fact that the flattened body is pointed at both ends. The common European species (*Amphioxus lanceolatus*) (fig. 170) is found on the Mediterranean and both Atlantic coasts, including our own islands. It is particularly abundant at Naples, where the

fishermen use it as bait. The translucent body varies in length from about 1½ inch to rather more than double that size, and at first glance one might be puzzled to say which was the front end of the body, as no distinct head is present. On closer inspection, however, a little hood-like structure, fringed by slender

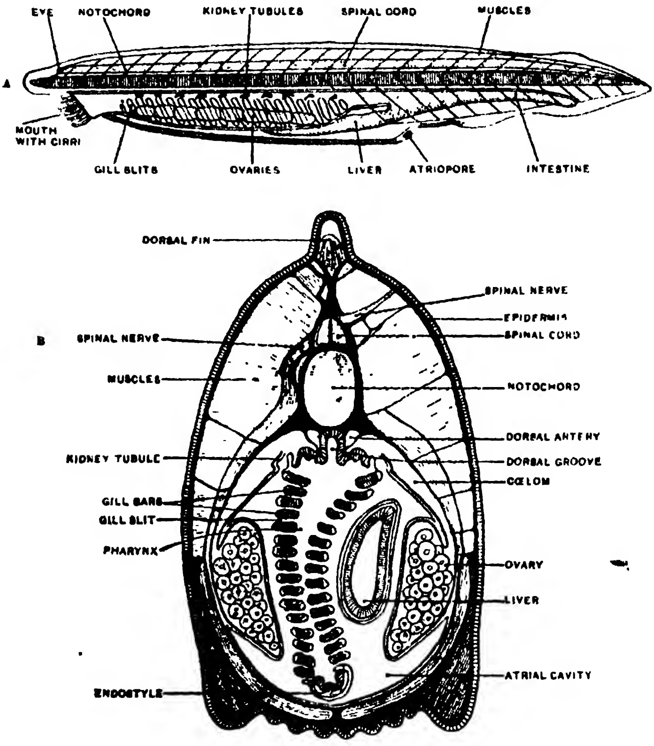


Fig. 170.—Lancelet (*Amphioxus lanceolatus*)

A, Side View, with internal organs seen by transparency. Semidiagrammatic. B, Transverse section Much enlarged and semidiagrammatic

tentacles, can be seen near one extremity. This marks the under side of the head end, and, since it leads to the mouth, has been called the *oral hood*, which has a certain resemblance to the mouth sucker of a Lamprey. Here as there jaws are absent, and the Lancelet is further devoid of the tooth-like projections and powerful rasping tongue which distinguish the Lamprey. Running along the upper margin of the body is a narrow *dorsal fin*, passing behind into a slightly expanded *caudal fin*, which again

is in one piece with a narrow *anal fin* running forward for a short distance. In front of this the under side of the body is broad, convex, marked by longitudinal pleats, and bounded on each side by a prominent fold which runs forwards to the oral hood. These two lateral folds converge behind and end where the anal fin begins. In the description of the Dog-Fish it was stated (p. 258) that the various unpaired fins are probably expanded surviving fragments of a continuous fin which, in ancestral forms, ran along the middle of the back, round the tail, and forwards for some distance along the under surface. Such a condition is actually represented by the Lancelet, for, as just stated, its unpaired fins constitute a continuous fringe to the body. But further, it is by no means improbable that the pectoral and pelvic fins of an ordinary fish represent the front and back ends of a continuous *lateral fin* which once existed on either side. There are no paired fins in the Lancelet, but the lateral ridges in front of the anal fin are perhaps equivalent to such continuous lateral fins.

The Lancelet is obviously segmented, *i.e.* divided into a number of similar successive parts from before backwards, and this segmentation is well seen in the muscles which make up a great part of the side of the body, these being divided up into >-shaped sections. At first view the animal looks as if it were bilaterally symmetrical, but this is not the case, for the muscle-segments do not correspond on the two sides of the body; and further, the external opening of the intestine (there is no cloaca) is placed on the left side of the body near the base of the tail-fin. There is also a lack of symmetry in other respects which need not be mentioned here.

A well-developed *notochord* is present, and like many of the other internal organs can be made out without dissection by examination of small specimens mounted whole as microscopic objects. There is, however, one peculiarity about it. Instead of stopping short about the middle of the brain, as it does in the higher Vertebrates, it runs to the extreme front, and the scientific name of the sub-class alludes to this (Gk. *cephalon*, head; *chordē*, string).

No *gill-slits* are visible on the exterior, but dissection shows that a very large number are present as oblique openings in the wall of the large pharynx. They do not, however, open directly

to the outside, but into a large *atrial cavity* which surrounds the pharynx, and which itself opens to the exterior by a rounded hole, the *atriopore*, on the under side of the body just in front of the anal fin. The state of things may be more clearly understood by reference to the development of the tadpole (p. 254), where the gill-slits at first open directly to the exterior but are

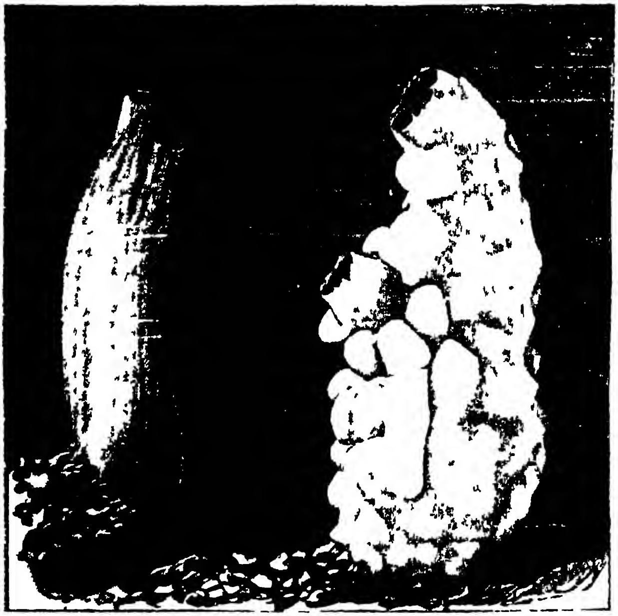


Fig. 172.—Two Simple Ascidians. 1. *Ciona intestinalis*. 2. *Phallusia mammillata*.

later on covered over by the backward growth of a fold of the body-wall, the upshot of this being the formation of a branchial chamber into which the gill-slits open, and which opens to the exterior itself by a small hole on the left-hand side of the body. If this hole were in the middle line below, instead of on the left side, it might be compared to the Lancelet's atriopore, while the branchial cavity has much the same relations as the atrial cavity. It would probably be incorrect to consider the two cavities as closely equivalent, for they develop in very different manners.

The Lancelet will also stand the third test of a Vertebrate, for it possesses a tubular *nerve-cord*, situated above the notochord,

but not extending so far forwards. There is, however, no distinct brain

It is usual to find this animal buried in the sand in a vertical position, with the head end projecting; but it can also swim, and is able to burrow in the sand with great rapidity.

SUB-CLASS II SEA-SQUIRTS (UROCHORDA)

Among the objects cast up by the tide on the sea-shore, or found attached to rocks which are uncovered at low-water, are certain leathery looking objects which when touched emit a jet of water, a habit which has earned for them the name of *Sea Squirts* On account of the firm cover or tunic with which they are invested the name of Tunicates has also been widely used They are the first fixed or sedentary animals with which we have had to deal and this mode of life has had a profound influence upon their structure A common British species *Ascidia mentula*, may be taken as an example

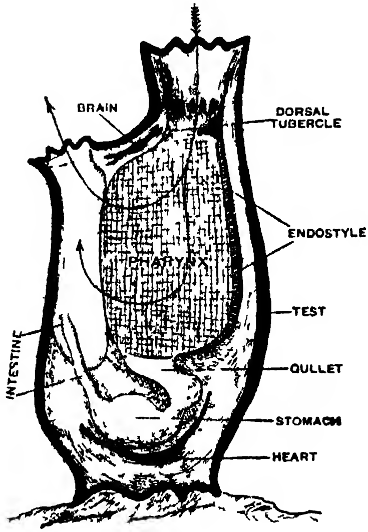


Fig. 172 Diagram to explain structure of a simple Ascidian The animal is seen from right side with dorsal surface to left and front end above The arrows indicate course of water currents which take food and oxygen into mouth pass through perforations in pharynx into atrial cavity and carry waste products to exterior through atriopore

The plump rounded body is attached by one end to some foreign object, while at the other end may be seen two orifices (see p 296, fig 171), each placed on a projection, so as to give a distant resemblance to the skin bottles used in the East, and which is embodied in the name of Ascidians (Gk. *askos*, a wine-skin, *eidos*, like) often applied to these forms One of the openings is situated at the extreme end and the other somewhat on one side. The former is the *mouth* and the latter the *atriopore*, and observation of a living specimen placed under water will show that currents set into one and out of the other. The protective tunic or *test*, which is thick and gristly in texture,

is interesting on account of its chemical composition, as it is largely made up of a substance, cellulose, which is almost entirely confined to plants. Dissection (fig. 172) fails to show the presence of a notochord, and the central nervous system merely consists of an elongated thickening or *ganglion*, placed about half-way between the two apertures, but the pharynx is perforated for breathing purposes as in ordinary Vertebrates. The mouth, in fact, leads into a large branchial sac or *pharynx*, perforated by innumerable small holes and suspended in an atrial cavity which opens by the atriopore already mentioned. There is therefore a general resemblance to the Lancelet in this respect, but in this case the intestine also opens into the atrial cavity.

Were we to rely only upon the anatomy of the adult we should hesitate before placing the Sea-Squirt among the Vertebrates, seeing that it conforms to only one of the three chief tests; but the matter is set definitely at rest by a study of the development. The egg of Ascidia becomes a tadpole-shaped *larva* in which a *notochord* is present, though it is confined to the tail, and for that reason is often called a urochord (Gk. *oura*, tail; *chordē*, string), which gives the name Urochorda, adopted at the head of this section as the name for the group of Sea-Squirts generally. And further, the ascidian tadpole is possessed of a hollow brain and spinal cord situated on the dorsal side of the body, besides which it may be noted that the perforations in the pharynx are at first of simple character, consisting of paired openings suggestive of the gill-clefts of fishes, &c.

After leading a free life for some time the tadpole attaches itself by means of adhesive projections situated at the head end, the tail with its urochord gets smaller and smaller and ultimately disappears, while the central nervous system is simplified into a single solid ganglion. We have, therefore, the remarkable phenomenon of an animal which, when young, possesses the distinctive vertebrate characters, but loses most of them in the adult condition, becoming, so to speak, of lower grade. This is a good example of biological *degeneration*.

It is a singularly interesting fact that one or two small free-swimming Ascidians, of which the best known (*Appendicularia*) (fig. 173) occurs in British seas, retain throughout life the tadpole

form and the typical Vertebrate characters. It is possible that these are primitive forms which retain the features distinctive of the ancestral Ascidians, but it is also possible that we have a case of animals which have dropped the adult stage out of their life-history, just as the Mexican Axolotls appear to be doing (see p. 249).

Ascidians may be divided into Fixed and Free-swimming forms, each of which groups can be again split up into Simple

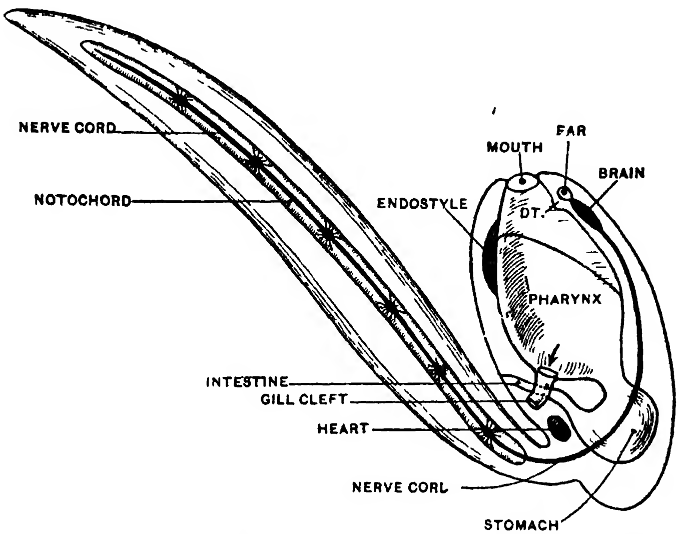


Fig. 173.—Diagrammatic drawing of Appendicularia, much enlarged, as seen from left side, with dorsal surface to right. D.T., Dorsal tubercle.

and Colonial species. The last expression needs explanation, as it involves a phenomenon of which no instance is furnished by the animals previously considered. All these are propagated solely by means of eggs, but in Ascidians and many of the lower Invertebrates there may be increase by means of outgrowth of buds (gemmation) or by the bodily splitting (fission) of individuals to form others. As this suggests similar processes among plants, it is commonly known as *vegetative propagation.* A collection of animals which have been formed in this way, and which remain united together, constitute a *colony*, or are said to be colonial. In Ascidians colonies may be formed by means of budding.

The individuals of *Fixed Ascidians* are of comparatively large size in the Simple forms (fig. 171), of which the example taken is a typical one. The Colonial forms are made up of smaller individuals, and the colonies produced may be of the most varying form and size, while the degree of union between the members of the colony is more or less complete. In such a native genus, for instance, as *Clavellina*, we find a creeping stalk-like structure from which a number of individuals grow up, each of them being essentially similar to Ascidia. A good example of more intimate union is found in *Botryllus* (fig. 174), which can often be found at low tide as a bluish gelatinous crust upon stones and brown sea-weed. Imbedded in this are star-shaped groups of small individuals.

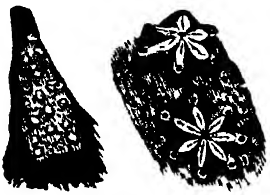


Fig. 174.—*Botryllus*.

To left, a s[illegible] of individuals [illegible] individuals [illegible] made up of seven mer[illegible] mouth [illegible]

Among *Free-swimming Ascidians* the only Simple forms are Appendicularia (fig. 17[illegible]) and its allies. The Colonial members include the remarkable phosphorescent *Pyrosoma*, which is shaped like a hollow cylinder closed at one end, and [illegible] of which more will be said elsewhere. Both are common in the Mediterranean.

SUB-[illegible] III. WORM-LIKE PROTOCHORDATES
([illegible])

Here are massed together a mixed number of forms about which there has been endless discussion, and of which the one with most certain tenure of Chordate rank is a worm-like creature which has no common name, but which may perhaps be called the Acorn-headed Worm (*Balanoglossus*) (fig. 175). It is found at low tide-mark in many parts of the world, living in mud or sand which it glues together into a sort of temporary tube by means of a slimy fluid poured out from the skin. One species is found in the Channel Islands. The front of the body is made up of a swollen *proboscis*, yellow or orange in colour, and capable of altering its shape to a very great degree. It is attached behind by a narrow stalk, and the general outline in

some species suggests the term "acorn-headed". The ***mouth*** is situated on the under side, at the base of this proboscis. **Next** comes a comparatively short region, named from its **appearance** the *collar*, while the rest, and by far the longest part, **of the** animal may be termed the *trunk*. On the upper side of **the** trunk, behind the collar, are a considerable number of *gill-slits* arranged in pairs, and forming the external apertures of *gill-pouches* which communicate internally with the digestive tube. They resemble in many respects the corresponding structures in the Lancelet. A small *notochord* has also been identified, but here we have the opposite extreme from what is found in an Ascidian tadpole, for the structure in question is a small rod which projects into and supports the base of the proboscis. It is in reality a thickened forward outgrowth from the digestive tube, and has a peculiar microscopic structure which is distinctive of notochords wherever they are found. The fact that it grows out of the gut is also a point in support of its notochordal nature, for in more typical cases, as e.g., **Lancelet or Frog, the** notochord arises as a thickening in the wall of the digestive tube. The remaining test of a Vertebrate **is also answered in** a fairly satisfactory way, for what **may be** described **as the** *central nervous system* in this creature **is a** more or less **hollow** thickening running along the dorsal **part** of the body **in the** collar region.

Fig. [illegible].—A[illegible] [illegible]

There are certain other more doubtful **claimants** to a **place** in the Hemichorda, but a discussion of their characters **would be** out of place in a preliminary sketch of the animal kingdom.

CHAPTER VII

BACKBONELESS ANIMALS (INVERTEBRATA). STRUCTURE AND CLASSIFICATION OF NEMERTINES AND MOLLUSCS

A brief account of the Backboned or Vertebrate animals has now been given, and in accordance with the usual custom from the time of Aristotle downwards all the remaining forms, far more numerous than they, may be conveniently lumped together as Backboneless animals or Invertebrates, divisible into a number of great groups or phyla, each of which is on a footing with the phylum Vertebrata. The lower Invertebrates are so unlike the Vertebrates that close comparison is not possible, but there are certain features which broadly serve to mark off a higher Invertebrate from a typical backboned animal. These are, to a large extent, implied in the summary given previously (pp. 60–63) of the chief Vertebrate characters, but it may be useful at this point to take such a form as a Cray Fish or Lobster and point out the distinctive features in question (fig. 176).

The body of a *Lobster* has the same two-sided or bilateral symmetry as that of a Vertebrate, and there is a clear distinction between front (anterior) and back (posterior) ends, upper (dorsal) and lower (ventral) surfaces, and right and left sides. The body, too, is segmented, or divided into a number of similar parts from before backwards, as in, say, a Lancelet. This is evident in the Lobster's tail. It must not, however, be hastily assumed that a segment of a Lobster is the exact equivalent either of a Vertebrate segment or a segment in an Invertebrate from another group.

Now come a number of important differences. A large number of jointed *limbs* are present, arranged in pairs, while a Vertebrate has at most two pairs of limbs, though these may differ in nature in different animals, and in the simplest case, that of fishes, are unjointed fins. The limbs are modified for

various purposes. The most obvious are those which end in the large pincers, behind which four large pairs of walking-legs are apparent. Under the head are a number of overlapping limbs, turned somewhat forwards, which guard the mouth and act as jaws. In a Vertebrate the jaws are part of the bony framework of the head, helping to bound the mouth-cavity, and the lower jaw works up and down. But the limb-jaws of the Lobster are outside the opening of the mouth, and from the nature of the case work against one another from side to side. To realize this, raise your hands to your mouth and "clap" them together, which will give an idea of the way in which one pair of the Lobster's jaws are worked. Six pairs, however, are present in all.

By combining the knowledge obtained by dissecting one Lobster from the side and making a cross-section through another, the following distinctive characters of higher Invertebrates can be easily verified:—

1. There is a protective *external skeleton* (exoskeleton) but no internal skeleton (endoskeleton), *i.e.* nothing can be discovered equivalent to the skull, backbone, &c., of, say, a Perch, or to the notochord of a Lancelet. The absence of endoskeleton modifies the structure in many ways, as, *e.g.*, in regard to the attachment of muscles. In such a limb as the human arm the numerous muscles are attached to the bones, but in a Lobster's leg they are attached to the firm exo-skeleton.

2. The body is not a double but a *single tube* in structure.

3. The side-walls of the digestive tube are not perforated by gill-slits.

4. The *heart* is situated *dorsally*, the exact opposite of the Vertebrate condition.

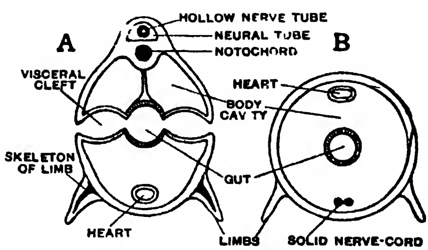


Fig 176.—Diagrammatic Cross-sections through, A, a Vertebrate, B, a higher Invertebrate

5. The *nervous system* consists of a *ring* surrounding the gullet, and continued backwards into a *ventral nerve-cord.* The dorsal side of the ring is thickened into a double *brain* or *cerebral ganglion.* A very large number of Invertebrates possess such a nerve-ring and ventral cord, while many more have the ring

though not the cord. In no Invertebrate does the central nervous system consist, as in Vertebrates, of a hollow cord running along the dorsal side of the body.

The contrasts between a Vertebrate and a higher Invertebrate are illustrated by the accompanying diagrams (fig. 176).

The following groups or *phyla* of the Invertebrata are recognized. It must not be imagined, however, that they are anything like of equal size, for some are exceedingly large, while others are relatively small.

I. Nemertines (NEMERTEA).—Worm-like marine forms, which in some respects approach the Chordata in structure.

II. Molluscs (MOLLUSCA), including such forms as Cuttle-Fishes, Snails, Slugs, Oysters, and Mussels.

III. Jointed-limbed Animals (ARTHROPODA), the largest group of the animal kingdom, comprising such creatures as Insects, Scorpions, Spiders, and Mites; Centipedes and Millipedes; Shrimps, Lobsters, and Crabs.

IV. Segmented Worms (ANNELIDA).– A large group of forms, including innumerable Marine Worms (free-living and tube-inhabiting), Earth-Worms, Fresh-water Worms, and Leeches.

V. Siphon-Worms (GEPHYREA).

VI. Wheel Animalcules (ROTIFERA).

VII. Moss-Polypes and Lamp-Shells (MOLLUSCOIDA). — The great bulk of these are fixed marine animals, and those belonging to the first group are nearly all colonial.

VIII Flat-Worms (PLATYHELMIA).—The most familiar of the forms grouped here are the Flukes and Tape-Worms, which are found as parasites within the bodies of other animals.

IX. Thread-Worms (NEMATHELMIA).—The name of the group indicates the shape of these creatures, most of which are parasites, either in plants or else within the bodies of other animals.

X. Echinoderms (ECHINODERMATA).—This phylum is constituted by such marine forms as Star-Fishes, Sea-Urchins, Sea-Lilies, and Sea-Cucumbers.

XI. Zoophytes (CŒLENTERATA).— Mostly marine animals, which may be either simple or colonial, fixed or free-swimming. Familiar examples are Jelly-Fishes, Sea-Anemones, and Corals.

XII. Sponges (PORIFERA).—Mostly marine, colonial, and fixed.

XIII. Animalcules (PROTOZOA). — This lowest phylum includes an immense number of simply-constructed animals, which are nearly always very small or microscopic in size. They are found almost everywhere, but are unfamiliar to those who are not in the habit of using the compound microscope.

A brief survey will now be made of these thirteen phyla, but many particulars regarding them will be found in other parts of this work.

NEMERTINES (Nemertea)

Although the worm-like forms which belong here have a wide distribution, and are particularly common between tide-marks on almost all coasts, they are nevertheless practically unknown except to the professed naturalist, and have received no common names. There are some forty British species. The vast majority are marine, and either shore or shallow-water forms, but they are also represented in fresh water and even on land. They have been given here the first place among Invertebrates, in deference to the views of many zoologists, in whose opinion they come near to the Protochordates.

The body of a typical Nemertine (fig. 177) is cylindrical, and presents no trace of segmentation. It may be only a small fraction of an inch in length, or in other cases many yards long. A common British form (*Lineus marinus*) is one of the species which are extremely elongated, and it may not infrequently be found under stones, with its slimy black body twisted up into a complicated coil. Other species may be more or less brightly coloured.

The *mouth* is a small oval opening on the under side of the head end, while the aperture of the intestine is at the extreme tip of the tail. Close examination will show that above the mouth on the front end of the body there is a small pore, and in a living specimen a narrow thread may sometimes be seen to shoot out from this pore, through which it can again be drawn back into the body. This thread is known as the *proboscis*, and, as described elsewhere, it is used as a means of killing or paralysing the marine worms upon which a Nemertine chiefly feeds. When within the body it is enclosed in a special sheath which overlies the digestive tube. The proboscis is hollow, and the way in which it is protruded and again drawn back may be understood by taking the somewhat hackneyed illustration of a glove with one finger. If this finger be pulled back into the main glove by turning it outside inwards, we shall have a rough model of the proboscis when lying within the body.

If now the finger be pushed out, it will represent the extended proboscis. The pulling in is effected by means of a muscle band which runs along the interior of the thread and is attached to its tip, while the pushing out is the result of fluid being squeezed into the thread from its sheath. This kind of principle is utilized elsewhere in the animal kingdom, and a very familiar example

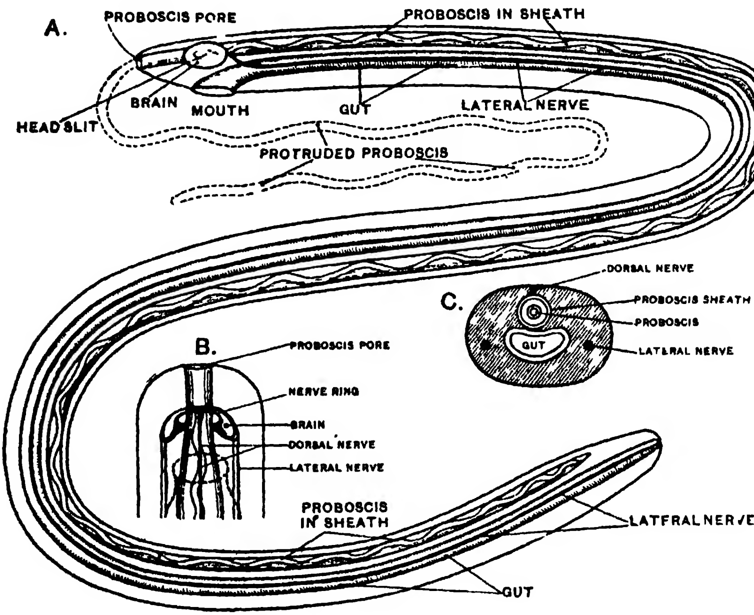


Fig 177.—Structure of a Nemertine (diagrammatic)

A, Side view, internal organs seen by transparency B, View from above of front end position of mouth and beginning of gut indicated by the dotted line C, Cross section

is found in the "horns" of the common Snail, which can either be stretched out (as immortalized in the nursery rhyme wherein the adventures of certain snail-hunting tailors are set forth) or withdrawn into the body at will.

Reasons have been adduced for thinking that the proboscis-sheath is comparable to a notochord, and the proboscis to a curious little structure attached to the under side of the brain in Vertebrates, and known as the pituitary body.

The *central nervous system* of a Nemertine is interesting in many ways. It consists of a *nerve-ring*, which encircles the front end of the proboscis, and not the digestive tube as is usual among

Invertebrates. Each side of the ring is thickened into a ganglion, from which a lateral nerve-cord runs along the corresponding side of the body, while there is a much more slender nerve running back in the middle line above from the upper side of the ring. This *dorsal nerve* has attracted a great deal of attention, for it has been compared to the spinal cord of a Vertebrate, though, unlike this, it is solid.

MOLLUSCS (Mollusca)

Molluscs include such familiar shell-fish as Periwinkles, Oysters, Cockles, and Mussels, as well as soft-bodied animals like Cuttle-Fishes, to which the term Mollusca (Lat. *mollis*, soft) was originally applied.

Examination of such a typical form as the Ormer or Sea-Ear (*Haliotis tuberculata*), which is common in the Channel Isles, will give some idea of the characters of Mollusca in general, and of the special subdivision to which this particular sea-snail belongs (fig. 178).

External Characters.—The most obvious feature is the presence of a large external *shell* covering the upper side of the body, from which it cannot be detached without cutting through a large rounded fleshy mass, the *shell-muscle*. The shell is not symmetrical, for a row of holes can be seen running along near its left margin, and on the right side at the back a spiral twist can be made out. Turning the animal over, a huge fleshy mass with a flattened surface is seen projecting from the under side of the body. By means of this *foot* the Ormer is able to adhere to rocks like a Limpet, and to crawl about like an ordinary Snail. A foot in some form or other is characteristic of all Mollusca, and it must be understood that the word is here employed with a special meaning of its own. Projecting in front from above the foot a short *head* can be seen bearing a blunt snout, at the end of which the *mouth* is placed, and a pair of pointed feelers or *tentacles*, which are solid, and cannot therefore, like those of a common Snail, be withdrawn into the body. Seen from below, the body of the Ormer is bilaterally symmetrical, and the twisted condition of its upper part is a special condition characteristic of snail-like forms in general.

On removal of the shell by cutting through the shell-

muscle the soft upper part of the body in which a large part of the viscera are contained will be exposed, and it will be noticed that this *visceral hump*, as it has been called, is twisted behind in correspondence with the twist in the shell. Skirting the visceral hump is a flap, produced by a pulling out, so to speak, of the body wall, and known as the *mantle*. In the Ormer it is narrow for most of its extent, but is very well developed in the part underlying the row of holes in the shell, where it roofs in a large *mantle-cavity*, which has a long slit-like aperture above and a wide opening in front about the head. That this mantle-cavity should freely communicate with the exterior is very necessary, for not only does it contain the breathing organs, but the intestine and the kidneys open into it. A very small amount of dissection reveals the presence of the breathing organs in the form of two plume-like *gills* attached along their sides, and having their tips pointing forwards. The projecting end of the intestine will also be seen, and right at the back of the cavity two small holes by which the kidneys open.

Just behind the mantle-cavity the *heart* is situated, consisting of a central *ventricle*, which pumps purified blood from the gills through *arteries* which come off from it fore and aft, and of a thin-walled *auricle* on either side. The ventricle is folded round the intestine, a noteworthy peculiarity, though one not known to have any physiological meaning. A heart like this, which contains pure blood only, is said to be *systemic*, and it should be noted how markedly it differs from the heart of an ordinary fish, which contains impure blood only. The complex heart of a Bird or Mammal is physiologically equivalent to both these varieties of heart, for its right half receives impure blood and pumps it to the breathing organs, while its left half is concerned with the reception of pure blood from those organs, and the distribution of the same to the general system.

The *digestive organs* of the Ormer consist of a long digestive tube with large glands opening into it, and including pharynx, gullet, stomach, and intestine, the last, as already noted, ending in the mantle-cavity. Particular interest attaches to the *pharynx*, or buccal mass, which is partly modified into a complex *rasping organ* (odontophore), characteristic of two great groups of the Mollusca. It essentially consists of a rounded cushion rising from the floor of the pharynx, over which is stretched from front to

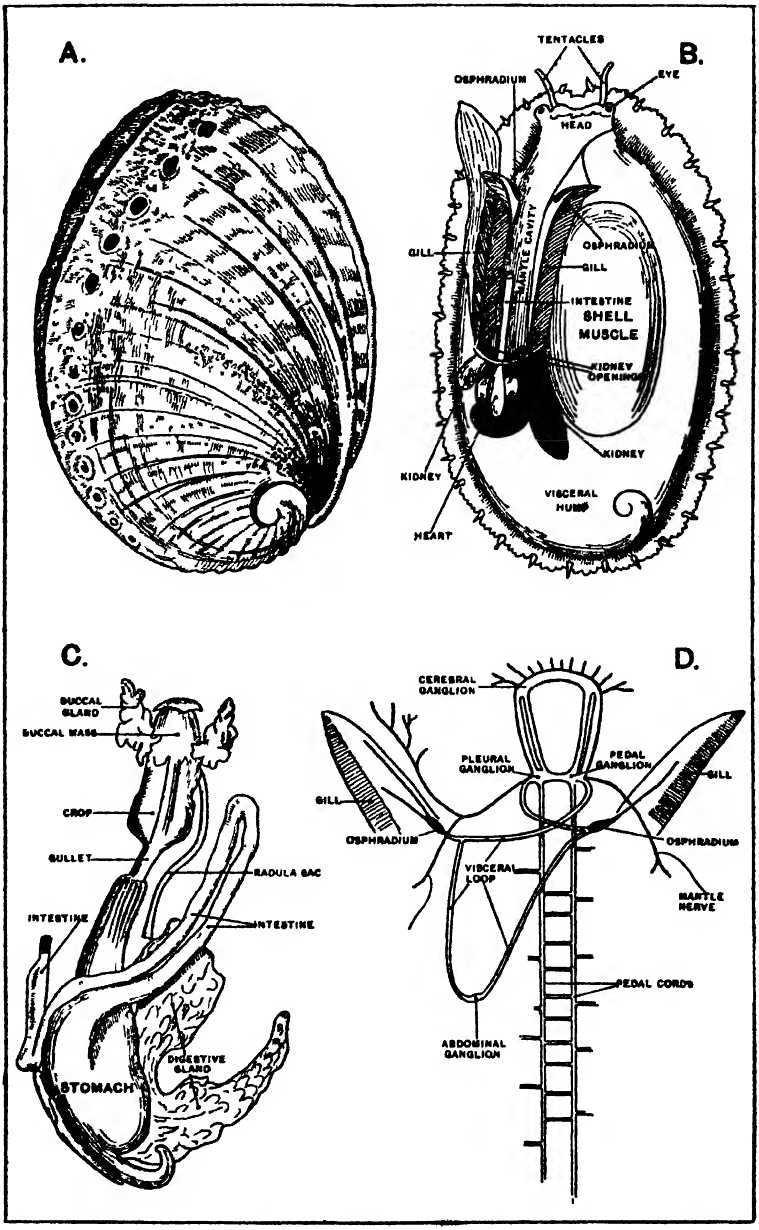


Fig 178.—Structure of the Ormer (*Haliotis*)

A, Shell from above. B, Semidiagrammatic view from above after removal of shell The roof of the mantle-cavity has been cut away and the heart exposed The small left kidney (unshaded) and hinder part of large right kidney (shaded shown by transparency C, Digestive organs. D Diagram of nervous system.

back a horny ribbon, the *radula*, beset with transverse rows of flinty teeth. This ribbon, often called the "tongue" or "palate", has often been compared to a finger-nail, and as worn away it constantly grows forwards from a projection (radula sac) at the back of the pharynx, just as the finger-nail does from its root. A fuller account of this organ will be given in another place.

The *kidneys* of the Ormer are two irregular brown bodies, opening as described. The left one is very small, and would seem not to act as a kidney at all.

There are certain characteristic features of the *nervous system* which require notice. It consists of a *nerve-ring* surrounding the beginning of the digestive tube, and of other connected parts. The upper part of the ring consists of a transverse band connecting two swellings, the *brain* (or cerebral) *ganglia*, and from each of these two cords run downwards to constitute one side of the ring. The outer cords end below in a pair of *lateral* (or pleural) *ganglia*, and the inner cords in a pair of *foot* (or pedal) *ganglia*, which are united together in the middle line so as to complete the ring below, while each lateral ganglion is also connected with the adjoining foot ganglion. From the brain ganglia, nerves run off to the sensitive parts of the head including the tentacles, and strong nerves to the foot run backwards through the substance of that organ from the foot ganglia. There still remains to be described a *nerve-loop*, which connects the two lateral ganglia and gives off nerves to some of the internal organs. It is a nerve-cord which, starting from one lateral ganglion, runs obliquely backwards, and, turning round in a curve at the level of the hinder end of the mantle-cavity, sweeps forwards again and takes an oblique course to the other lateral ganglion, taking altogether a course which may be compared to the figure 8. Three ganglia are seen as swellings upon this loop, one close to each gill, and the third at the back end of the 8. The curious course of the loop is one result of the twisting of the body which has affected both the visceral hump and shell.

The most important organs of sense are the *tentacles*, which have to do with touch, so-called *organs of hearing*, consisting of a pair of little rounded sacs attached to the foot ganglia, and two small cup-shaped *eyes*, one at the base of each tentacle. There is also a special sense-organ connected with each gill,

which is generally considered a kind of organ of smell, entrusted with the duty of testing the quality of the water which enters the pallial cavity. It is termed the *osphradium*.

The preceding account of the Ormer illustrates the most prominent characters of Mollusca generally, which are: (1) the absence of segmentation, (2) the presence of a *mantle*, (3) the muscular *foot*, (4) the systemic *heart*, (5) plume-like *gills*, and (6) a *nerve-ring* surrounding the first part of the digestive tube. The vast majority of Molluscs either possess all these characters or else a sufficient number of them to leave no doubt as to how they should be classified. Other very common, though by no means universal, characters of the group are the presence of a *shell* and development of a *rasping organ* (odontophore). Large numbers of Molluscs are also distinguished by the bilateral symmetry of their bodies, and though the Ormer is not one of these, it is, as already pointed out, symmetrical so far as the lower half of the body is concerned.

Five classes are recognized among Mollusca, as follows:—

1. Head-footed Molluscs (CEPHALOPODA), including the Pearly Nautilus, Cuttle-Fishes, Squids, and Octopi.
2. Snails and Slugs (GASTROPODA).
3. Bivalve Molluscs (LAMELLIBRANCHIA), including forms with the shell in two pieces, *e.g.* Oyster, Mussel, and Cockle.
4. Tusk-shells (SCAPHOPODA).
5. Proto-Molluscs (AMPHINEURA), a small group of which the only common member is Chiton, distinguished by the possession of eight overlapping shelly plates on the upper surface of the body.

CLASS 1.—HEAD-FOOTED MOLLUSCS (CEPHALOPODA)

As a good type for description we may select the Common Cuttle-Fish (*Sepia officinalis*), one of our native species, which preys upon fishes and crustacea in shallow water, and is a free-swimming form (fig. 179).

External Characters.—The body is bilaterally symmetrical, and at one end of it the *mouth* may be seen, provided with a pair of horny *jaws* resembling those of a parrot, and surrounded by ten arms or *tentacles*, of which two are very long and can be drawn back into special pouches. The inner sides of the eight short arms are studded with adhesive *suckers*, and each long arm swells at its end into an oval pad, one side of which is

similarly provided. Outside the circlet of arms a large *eye* can be seen on either side, covered by a circular eyelid perforated by a small hole. The presence of mouth and eyes shows that we are dealing with the head end of the animal. In comparing the body with that of the Ormer we must place this end downwards and slant the rest of the animal, which is mostly visceral

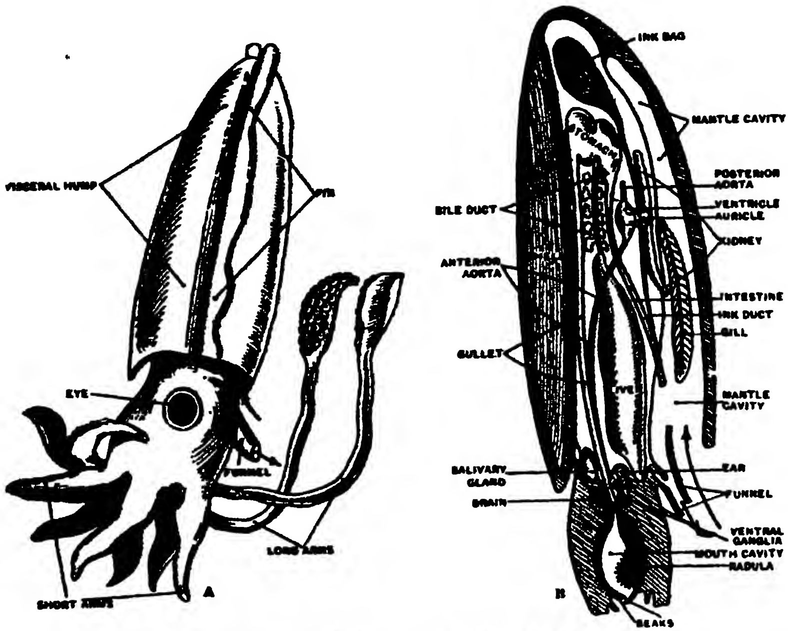


Fig. 179.—The Cuttle-Fish (*Sepia officinalis*) reduced
A, View from left side. B, Side-dissection. Arrows show course of water into and out of mantle cavity.

hump, upwards and backwards as shown in the diagram (A). It will then be clear that the long axis of the body is pretty nearly at right angles to the direction corresponding to the long axis in the Ormer. The long *visceral hump* will possess two gently-curved sides facing respectively forwards and backwards, and two sharp edges placed right and left and margined by a fin-like expansion. The next point will be to find mantle and foot. The former is readily made out running round the edge of the large visceral hump at its lower end, just above a narrowed "neck" indicating the boundary of the head. Most of it is at the back, where it constitutes the hinder wall of a large *mantle-cavity*, into which a large slit-like opening leads. The *foot* has grown

round the head, and chiefly consists of the ten arms or tentacles. It is from this peculiarity the name of the class is derived (Gk. *kephalon*, a head; *pous*, a foot). Just above the back of the head, and projecting from the opening into the mantle-cavity, will be noticed a muscular conical tube, the *funnel*, by the ejection of water through which the Cuttle-Fish is able to swim rapidly backwards. It will be observed that the mantle-cavity is here at the back, while in the Ormer it is in front, one result of the twisting which the visceral hump of that animal has undergone. In its natural position, whether resting on the sea-bottom or swimming, the front side of the head and visceral hump is directed upwards, and this side is much darker than the other. It may be taken as a general rule that the surface of an animal habitually facing in this direction is the darkest part of the body, though its actual nature varies in different animals. Here it is the front side, but in a Dog-Fish it is the true upper or dorsal side, and in a flat-fish either the right or left side according to the species (see p. 279). One peculiarity of the Cuttle-Fish's skin is especially noteworthy. If a living specimen is watched, it will be seen that beautiful purplish flushes of colour sweep over the body from time to time, leaving it comparatively pale in the interval. The cause of this is to be sought in the presence of innumerable little rounded *colour-bodies* (chromatophores), which, under the control of the nervous system, vary in size. When reduced to their smallest dimensions the skin is pale, but when fully expanded it is dark. A similar phenomenon has been described for the Frog (p. 251), where, however, the colour changes are comparatively slow.

Cutting open the mantle-cavity, we shall find similar parts and openings to those described for the Ormer (p. 308). In the middle line there is the projecting end of the intestine, and on either side of this a kidney aperture, while a plume-like *gill* is to be seen on either side. As is well known, the Cuttle-Fish and many of its allies are able to eject an inky substance into the surrounding water as a means of protection. This ink is formed within a rounded *ink-bag*, and carried off through a slender tube which has a common external opening with the intestine.

The front side of the visceral hump has imbedded in it a broad "cuttle-bone", composed of overlapping layers of cal-

careous material. This is to be regarded as a *shell*, and is not internal in the same sense as the internal skeleton of a Vertebrate, for it is inclosed in a pouch of the skin which has lost the opening to the exterior probably possessed by ancestral forms. Some Molluscs still exist in which the shell is almost but not quite covered by folds of the skin which have grown over it.

As regards the internal structure of the Cuttle-Fish, it need only be remarked that there is a very large *rasping organ* (odontophore); a systemic *heart*, consisting of a ventricle and two auricles; and a *nerve-ring*, swollen into very large ganglia and protected by a cartilaginous case.

The eggs are enclosed in oval cases which are united together into masses, that have been compared to bunches of grapes in appearance, and which are among the common objects cast up on the sea-shore.

Cephalopods are divided into two sub-classes, named, according to the number of gills: 1. Dibranchiata (Gk. *dis* twice; *branchia*, gills), of which the Cuttle-Fish is an example; and 2. Tetrabranchiata (Gk. *tetra*, four; *branchia*), of which the only living representative is the Pearly Nautilus.

Sub-class 1.—CUTTLE-FISHES (Dibranchiata)

This sub-class is again divided into two groups, *Decapoda* with ten arms, and *Octopoda* with eight. The former includes the Cuttle-Fishes, of which Sepia is a type, the Squids, and Spirula. Squids, or, as they are sometimes termed, Calamaries, have an even wider distribution than Cuttle-Fishes, for they are not only found in coastal waters, but are also pelagic, *i.e.* living in the open sea, where shoals of them are met with. A common Atlantic and Mediterranean species which abounds on our shores is the Common Squid (*Loligo vulgaris*). This animal is of more slender build than the Cuttle-Fish, and a large triangular fin projects from each side. The shell or "pen" is a narrow horny structure, shaped like a lance-head. The old name Calamary for creatures of the kind was given in allusion to this "pen" (L. *calamus*, a quill), its shape being compared to a short quill.

Some of the Squid family attain gigantic dimensions, and there can be little doubt that specimens of the kind are largely responsible for the numerous tales and legends which

exist regarding a supposed marine monster, the Great Sea Serpent, or Kraken. Actual measurements which have been made from time to time of bodies or portions of the bodies of such creatures leave no doubt that a total length of over 50 feet may be attained, the greater part of this, however, being taken up by the long arms. Gigantic Squids of the kind are sometimes cast ashore on the western coasts of Britain among other localities.

Fig 180.—Spirula

Spirula (Fig. 180) is a small animal in which the shell is spiral and divided into numerous chambers by transverse partitions. It is partly enclosed in folds of the skin. The animal itself is but rarely met with, though its shells are common on Pacific shores and may be seen in most museums.

The *Octopods*, or 8-armed Cephalopods, differ from the Cuttle-Fishes and Squids in the absence of the two long arms, besides which they are entirely devoid of an internal shell. The visceral hump is short and rounded, and the suckers on the arms are unstalked. The group includes the Octopi and their allies, and the Paper Nautilus or Argonaut.

The Common Octopus (*Octopus vulgaris*) is common on rocky shores on the margins of both Atlantic and Mediterranean, lurking in crevices, crawling by means of its sucker-studded arms, or swimming swiftly backwards like the Squids. Each arm is provided with two rows of suckers, while in an Octopod, common on British coasts, *Eledone moschata*, there is only one. The specific name of this particular species, which is eaten by the Italians, has reference to the strong musky odour of the animal.

Some Octopods attain a very large size, though they are inferior to Squids in this respect. Large specimens are reputed to be common on the shores of the island of Sark in the Channel group, and a well-known description of an imaginary combat with one of these is given in Victor Hugo's *Toilers of the Sea*.

The Argonaut or Paper Nautilus (*Argonauta argo*) is a pelagic form, common in the Mediterranean, in which the female is provided with a thin cap-shaped shell, which is symmetrical, and

large enough to contain the entire body of the animal. It is mainly secreted by the inner surfaces of two of the arms, which are dilated at their ends into large lappets. By means of these the animal holds on to the shell, which is not attached to it by any muscular or fibrous tissue.

Sub-class 2—PEARLY NAUTILUS (Tetrabranchiata)

The only living representative of this is the Pearly Nautilus, of which the best-known species (*Nautilus pompilius*) (fig. 181) has a wide distribution in the Indian and Pacific Oceans. The animal is enclosed in a large spiral shell, of which the coiled-up portion projects forwards towards the animal's front end. The body does not occupy all the shell, for a considerable part of this is divided into a series of gas-containing chambers by means of curved partitions, concave towards the external aperture. The last and broadest part forms a body-chamber in which the animal is contained, the rounded end of its visceral hump resting against the concave surface of the last partition. The shell grows in size by successive additions to its aperture or mouth in accordance with the growth of the animal, and at the same time the older part of it is from time to time cut off by formation of a new partition, the body slipping forwards, as it were, so as to permit of this. The old chambered part of the shell is not, however, entirely devoid of soft parts, for each partition is perforated in the middle by a hole continuous with a short tube directed away from the body-chamber, and in this way a hollow structure know as the *siphuncle* is constituted,

Fig. 181.—Pearly Nautilus (*Nautilus pompilius*). The left half of its shell has been removed

which is traversed by a fleshy cord, continuous almost like a tail with the rounded end of the visceral hump. This is also connected with either side of the body-chamber by means of a broad shell-muscle. The shell consists of an external membrane exhibiting brown and white marking, a white porcelain-like layer, and an internal layer possessing a beautiful pearly lustre, the appearance of which has suggested the ordinary name of the animal.

The *foot* is not constituted by long tentacles or arms as in the Cuttle-Fishes, &c., but consists of a number of lobes upon which are borne a large number of slender adhesive tentacles, the tips of which can be drawn back into sheaths. A *funnel* is present as before, but instead of being a complete tube it is made up of two halves which are rolled upon each other. Within the mantle-cavity, which occupies the same relative position as in a Cuttle-Fish, there are four instead of two plume-like gills, and in correspondence with this the heart has four auricles, one for receiving the purified blood from each gill, and there are four instead of two kidneys. The *eye* is of extremely simple structure, and has been compared to a pin-hole camera, consisting as it does of a deep cup, which would be closed externally were it not for the presence of an extremely small rounded aperture like a pin-hole.

CLASS 2.—SNAILS AND SLUGS (GASTROPODA)

The Ormer already described (pp. 307-311) belongs to this class, that includes a very large number of species, of which the vast majority are distinguished by the presence of a head bearing tentacles, a flattened creeping foot, and a shell which consists of only one valve or piece, and is therefore said to be ***univalve.*** The class is split up into smaller divisions as follows:—

Sub-class 1.—Streptoneura (Prosobranchia).

Order (1). Comb-gilled Snails (Ctenobranchia).
Order (2). Shield-gilled Snails (Aspidobranchia).

Sub-class 2.—Euthyneura.

Order (1). Hind-gilled Snails (Opisthobranchia).
Order (2). Lung Snails and Slugs (Pulmonata).

Sub-class 1.—STREPTONEURA (Prosobranchia)

This subdivision of Gastropods is partly founded on the course taken by the nerve-loop which is attached to the nerve-ring. It is here twisted, as, *e.g.*, in the Ormer (see p. 310), into a shape resembling the figure 8. Another important feature is afforded by the gill or gills which, when present, are in front of the heart, as again in the Ormer (see p. 308). These Molluscs may therefore be termed "fore-gilled" or *prosobranch* (Gk. *pro*, in front of; *branchia*, gills). They include most of the marine snails which are to be found on the sea-shore. On the shape of the gills, among other characters, the two orders of the sub-class are marked off from one another, *i.e.* (1) *Comb-gilled Snails*, with a single gill consisting of an axis bearing a series of small flattened plates, comparable to the teeth of a comb; and (2) *Shield-gilled Snails*, in which there are two series of such plates, one on each side of the gill-axis. In some members of the second order two gills are present.

Order (1). *Comb-gilled Snails* (Ctenobranchia).—This order is divided into no less than fifty-nine families, so that space will prevent more than a brief notice of a few common forms.

Probably no sea-snail is more familiar than the Periwinkle (*Littorina littorea*), common on the rocks between tide-marks, and illustrating a number of points in which the members of the order differ from the Ormer and related forms. The thick rounded shell is obviously spiral, and the visceral hump it covers is of the same shape. The spiral, as in most snails, is a right-handed one, *i.e.* with its turns running in the same direction as an ordinary screw or corkscrew, so that if the shell be placed on end with apex above, its turns or whorls will be seen to slope up from left to right. The most primitive Molluscs known are bilaterally symmetrical, devoid of a prominent visceral hump, and with a posterior mantle-cavity into which the intestine, &c., open. Such spirally-twisted forms as Periwinkle have apparently arisen from simple forms of the kind by development of a visceral hump, together with a strong shell to cover it, and also to serve as a shelter into which the animal might withdraw itself. At the same time twisting took place, perhaps as a result of the weight of the parts, and the result has been that mantle-cavity, end of intestine, gills, heart, and kidneys have been brought

round to the front (fig. 182). It is at any rate pretty clear that a spiral hump and shell are more compact and convenient than a much elongated hump covered by an extinguisher-shaped shell. In most cases the twisting, as viewed from above, has taken place in a direction opposed to the hands of a watch, but in some few snails the opposite has been the case, so that the spiral shell is left-handed.

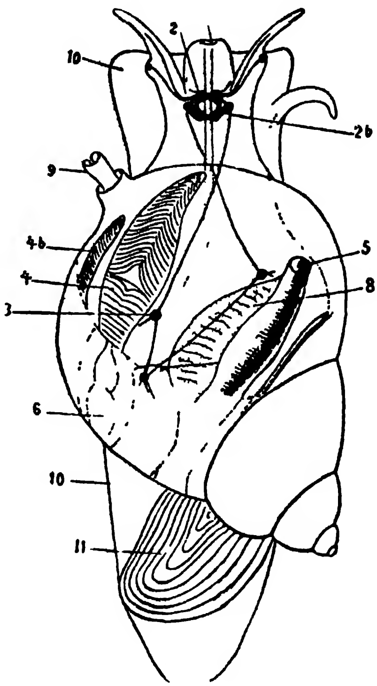


Fig 182 —Diagram of a Comb gilled Snail seen from above. The roof of mantle cavity and overlying shell supposed transparent

1 Mouth 2, brain ganglion 2b, nerve cord connecting side ganglion above with foot ganglion below 3 one of the three ganglia on the twisted nerve loop 4 gill 4b osphradium 5, opening of intestine 6 heart in pericardium 8 a gland (purple gland in Purpura 9, siphon 10, 10, foot, 11, operculum

A little observation at the sea-side will show that Periwinkles are in the habit of creeping about on the rocks, feeding on sea-weed, from which they are able to scrape small pieces by means of the rasping organ. The part of such an animal which protrudes from the shell will be seen to be bilaterally symmetrical, and to mainly consist of a foot much smaller than that of the Ormer (see p. 307), and a head provided with a prominent snout and two tentacles, each of which bears a small eye at its base in the form of a black spot. The projecting hind-end of the foot bears upon its upper side a horny plate, the *operculum*, which when the animal is completely withdrawn into the shell by means of the shell-muscle stops up the aperture, thus guarding the only weak point in the defences. The operculum corresponds in shape with the aperture or mouth of the shell, which here, as in vegetarian snails generally, possesses a continuous margin devoid of any notch.

Examination of the mantle-cavity and the related organs will show several important points of difference from the Ormer (see p. 308). As before, the last part of the intestine can be

seen, lying, however, well over on the right side, while on the left there is a single *gill* with the comb-like shape characteristic of the order, and running alongside it a projecting ridge, the *water-testing organ* (osphradium). The *heart* is placed immediately behind the gill, and has but one auricle, placed in front of the ventricle, which is not folded round the intestine as in the Ormer. It is indeed exceptional for the intestine of a snail to run through the heart, though it is characteristic of bivalve molluscs. There is but one *kidney* in the Periwinkle, opening into the back of the mantle-cavity, on the left-hand side. The suppression of one gill, auricle, and kidney is believed to be one result of the twisting of the body, though exactly why is uncertain. They have perhaps been subjected to pressure, and so to speak squeezed out of existence. The twisting of the visceral loop in the nervous system is another result of the coiling of the body, and this is easily understood.

Two species closely related to the Periwinkle are common on British coasts. In one (*Littorina rudis*) the coiled apex or spire of the shell is very short. The other (*L. obtusata*) is a small form, varying in colour from greenish-brown to orange-yellow, and entirely devoid of a projecting spire, the apex of the shell being rounded off so as to make the general outline of the shell spheroidal. It is common on the brown sea-weed (*Fucus*) with which 'tween-tide rocks are often thickly covered.

The River-Snail (*Paludina*), common in the streams of this country, is something like the Periwinkle in general shape, but it is a good deal larger and the shell is much thinner.

Living side by side with the Periwinkle on our rocks will be found the Purple Snail (*Purpura lapillus*), with a dense angular white shell extremely unlike the rounded covering of the former species. It belongs to a different family, and is a good example of a carnivorous sea-snail. The mouth of the shell is notched at its front end, *i.e.* the end away from the spire, for the transmission of the *siphon*, a spout-like prolongation of the mantle by means of which water enters the mantle-cavity. The Purple is one of the forms in which the pharynx with its rasping organ is situated in the end of a long *proboscis*, that is retracted when not in use. The typical genus of this particular family is *Murex*, many of the tropical species of which possess extremely beautiful shells, covered with long spines and having the front angle of

the mouth drawn out into a long canal for the reception of the siphon. Tyrian purple was obtained from species of Murex and Purpura, the organ yielding it being a gland in the roof of

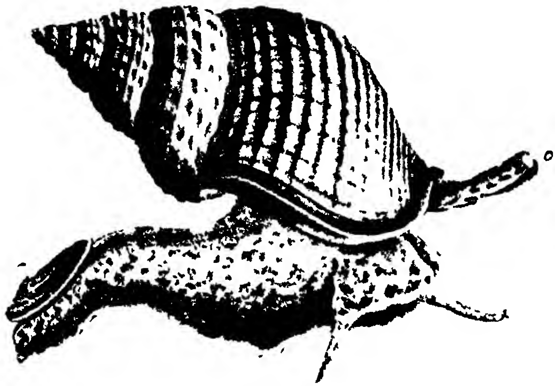


Fig 183 —Whelk *Buccinum* *a a*, tentacles *s* siphon *o*, operculum

the mantle-cavity, of which the juice turns purple on exposure to sunlight.

The Common Whelk (*Buccinum undatum*) (fig. 183), inhabiting both shallow and deep water around our coasts, closely resembles the Purple in structure, but is very much larger.

Fig 184 Olive (*Oliva*)

As examples of other families may be mentioned :- Mitre-Shells (*Mitra*), Volutes (*Voluta*), Olive-Shells (*Oliva*) (fig. 184), Harp-Shells (*Harpa*), Cone-Shells (*Conus*), Turret-Shells (*Turritella*), Wing-Shells (*Strombus*) (fig. 185), Helmet-Shells (*Cassis*), and Cowries (*Cypræa*) (fig. 186). In many of these the shells are extremely handsome, and occupy a prominent place in museums and private collections.

Special mention must be made of the *Heteropods*, a group of comb-gilled snails which swim freely in the open sea. The body in these pelagic forms is transparent, and the foot is a laterally-flattened fin-like structure, by means of which the animal swims back downwards. The shell may be spiral (*Atlanta*) or cap-shaped (*Carinaria*), but in some cases (*Pterotrachea*) is entirely absent.

Order (2). *Shield-gilled Snails* (Aspidobranchia).—As already mentioned, these forms possess a gill or gills in which the axis has a series of plates on either side. The primitive bilateral

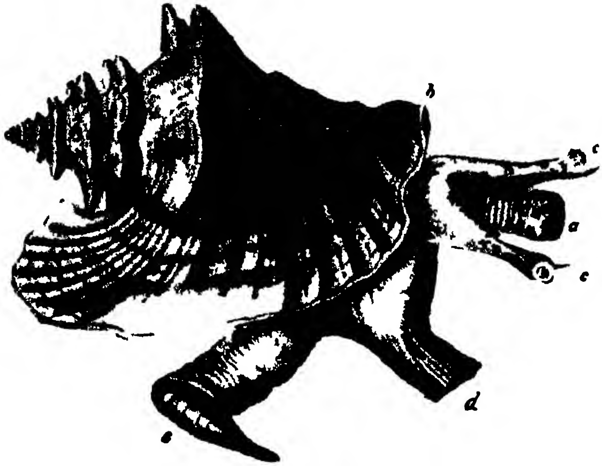


Fig. 185.—Strombus.
a, Proboscis; *b*, notch in shell mouth; *c*, eye-bearing tentacles; *d*, foot; *e*, operculum.

symmetry of the body has not been disturbed to the same extent, for both right and left gills, auricles, and kidneys may be present.

There are fifteen families, of which one, the *Trochidæ*, represented by twenty British species, may be taken as representing forms with well coiled shell, the colours and markings of which are often of extreme beauty. Two auricles and kidneys are present, but only one gill.

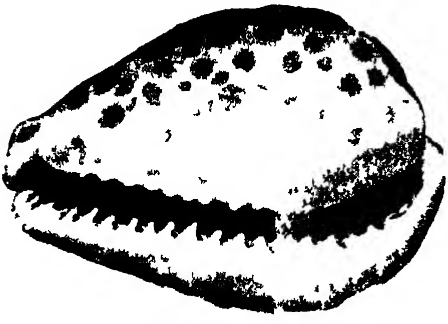


Fig. 186.—Cowry (*Cypræa*).

The Ormer (*Haliotis tuberculata*), already described (pp. 307–311), is the type of another family, and, as we have seen, it possesses two auricles, gills, and kidneys. There is good reason to believe that it is descended from forms possessing a well-coiled visceral hump, covered by a shell of corresponding shape, and large enough to serve as a retreat into which the animal could withdraw itself at the approach

of danger. Although the hump and shell still retain a certain amount of twisting they have been flattened out to a large extent, and the shell no longer serves as a refuge. This, however, is made up for by the immense size of the foot, by which the animal can adhere firmly to the rock, at the same time pulling the shell down so as to cover the exposed parts.

In the much smaller Key-hole Limpet (*Fissurella Græca*) of the Mediterranean the visceral hump is completely flattened out, and the shell is conical, with a hole at the apex communicating with the mantle-cavity. It possesses two gills, &c., like the Ormer.

In John Knox's Limpet (*Acmæa testudinalis*), not uncommon on certain parts of the British coast, still further changes have taken place, for there is only one auricle and a single gill. Nor does the intestine pass through the heart, as is the case in the shield-gilled forms so far mentioned. The Common Limpet (*Patella vulgata*) agrees with this species in most respects, but has lost both the gills, at least as functional breathing-organs. If the small mantle-cavity lying above the neck be cut open the end of the intestine will be seen projecting into it, and on each side of this the opening of a kidney. On the floor of the cavity are two little orange-coloured projections, examination of which as to structure and nerve-supply shows that each represents the vestige of a gill covered by its water-testing organ (osphradium). The Limpet, however, does possess *gills*, though of another kind, which are seen as a large number of flattened plates running right round the body well above the foot and overhung by the mantle skirt, which is a well-developed continuous flap. Since these gills are not the equivalents of the ordinary plume-like gills characteristic of Molluscs they are termed *secondary* gills. This use for the word secondary is a common one in zoology.

At first sight a Limpet, with its simple conical shell, might be taken for a very primitive animal. If it were so, however, the mantle-cavity, with its related organs, would be at the hind end of the body instead of in front, and the nerve-loop of the nervous system would not be, as it is, 8-shaped. These considerations, and comparison with other forms, would lead to the conclusion that the apparent simplicity is secondary, and that the Limpet's ancestors were forms with spirally coiled visceral hump and shell. A very interesting confirmation of this con-

clusion is afforded by the life-history, for at an early period of its existence, when it is a free-swimming larva, it actually does possess spirally twisted visceral hump and shell. This is another example of the law of recapitulation previously exemplified (see p. 14).

Sub-class 2.—EUTHYNEURA

These are forms in which the nerve-loop of the nervous system is not twisted (except in one family), but it would appear that this is not, as might at first sight be supposed, a primitive feature, but the result of an untwisting process. A further character is the possession of two pairs of tentacles by the head. There are two orders: 1. Hind-gilled Snails (Opisthobranchia), with the auricle of the heart behind the ventricle, and the gill in a corresponding situation; and 2. Lung Snails (Pulmonata), in which the gills are entirely absent and the mantle-cavity has been converted into a lung.

Order 1.—HIND-GILLED SNAILS (Opisthobranchia)

A very great variety of marine forms are placed in this order, some snail-like in appearance, others slug-like, and others again of modified shape and adapted for swimming in the open sea. A distinction is drawn between species in which there is typically a gill sheltered in the mantle-cavity (Tectibranchs), and the Sea-Slugs (Nudibranchs), devoid of mantle and shell.

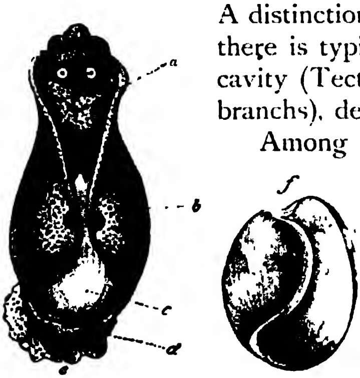


Fig 187 — Bubble-shell (*Bulla*) *a*, Head-lappets; *b*, right epipodium; *c*, shell; *d*, mantle-lobe; *e*, hind-end of foot; *f*, shell.

Among the *Tectibranchs* the Bubble-Shells possess a thin translucent spiral shell (fig. 187), overlapped by a body-fold (epipodium) each side.

Another related family is exemplified by a small white mollusc, *Philine aperta*, very common in shallow water round the British coast. The shell is something like that of a bubble-shell, but is not visible externally, as folds of the mantle have grown completely over it. In the Sea-Hare (*Aplysia*) the shell is still further reduced, being a thin oval plate situated on the upper

side of the body and almost entirely covered over. A large *gill* is present, protected in a *mantle-cavity* which opens on the right-hand side (see fig. 188). The external opening of the single *kidney* is at the root of the gill, and the intestine terminates still further back outside the mantle-cavity altogether. The Sea-Hare was at one time pointed to as a good example of a form in which the twisting process had begun, carrying the mantle-cavity with its organs on to the right side. If this were so, however, we should expect to find two auricles to the heart, two gills, and two kidneys, which is not the case. A more adequate explanation is that the Sea-Hare is descended from forms in which coiled visceral hump and shell were present, and which had lost an auricle, a gill, and a kidney; forms, in fact, resembling such a species as the Periwinkle in structure (see p. 318). We must suppose that in these the visceral hump gradually flattened out and the shell gradually became reduced, while at the same time a certain amount of untwisting took place, bringing back the mantle-cavity to the right-hand side of the body. In this way a secondary or spurious simplicity has been acquired. The non-twisted nerve-loop (fig. 188) is characteristic of Euthyneura generally.

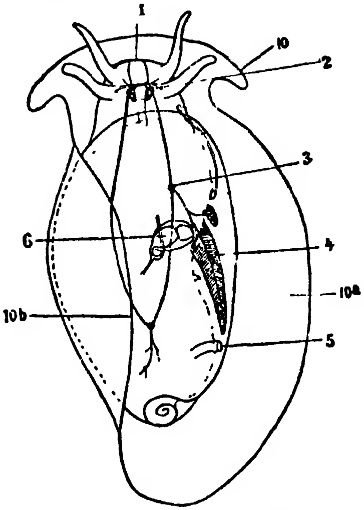


Fig 188 —Diagram of a Tectibranch Snail, seen from above

1, Mouth, 2, nerve ring with ganglia 3, one of the two ganglia on the untwisted nerve-loop, 4, gill, just in front of which is seen the osphradium, 5, opening of intestine, 6, heart in pericardium 10, 10a, right epipodium, 10b, left epipodium folded over back.

Eight out of the twenty families embraced by the Tectibranchs are collectively known as the *Wing-footed Snails* or *Pteropods* (Gk. *pteron*, a wing; *pous*, a foot), formerly regarded as a distinct class of the Mollusca. They are small pelagic creatures, vast shoals of which are to be found swimming in the open sea. Some of them possess a mantle-cavity and a transparent shell either spiral or conical in shape. In these the foot is transformed into a pair of fin-like structures. Others again have no mantle and shell, and though they possess fins,

these are not formed from the foot, but from the region of the body immediately above it, and equivalent to flaps found in this position in the Sea-Hare (epipodia) or to the halves of the funnel in a Pearly Nautilus (see p. 317).

Sea-Slugs (Nudibranchs).—These are beautifully coloured creatures with a large creeping foot. Their symmetrical form is not a primitive character, but due to the untwisting process just described for the Sea-Hare. Here, however, modification has gone a stage further, for not only is there no shell, but both mantle-cavity and the typical plume-like gill are absent. The intestine opens in the middle line on the posterior part of the body.

A common British genus is *Doris*, in which the absence of plume-gills is made up for by the presence of a circlet of branched *secondary gills* situated on the upper side of the body around the opening of the intestine. If the expanded gills of a living specimen be touched they are immediately drawn in, being sheltered in a ring-like groove when so retracted. Another common genus is *Eolis* (fig. 189), in which the back is studded with numerous slender club-like processes.

Fig. 189. Eolis.

A very interesting little Nudibranch is the free-swimming Mediterranean form *Phyllirhoë*, which possess a transparent laterally-flattened body and is devoid of foot. There are numerous little phosphorescent bodies in the skin.

Order 2.—LUNG SNAILS (Pulmonata)

The seventeen families of this order are mostly inhabitants of the land or of fresh-water, and familiar examples are furnished by the land-snails and slugs. The common Garden Snail (*Helix aspersa*) may be taken as an illustrative type (fig. 190).

The part of the body which is protruded from the shell when the animal crawls is symmetrical, and its under part is made up of the well-developed *foot*, which has a rounded front end and ends in a point behind. The head is fairly distinct, and bears

two pairs of *tentacles*, which are hollow and can be drawn back into the body. The front pair are short, while the others are long, and each of them bears an eye at its tip. There is a well-coiled *visceral hump* covered by a *shell* of corresponding shape, into which the animal can be withdrawn, though there is no operculum to guard the entrance. During the winter the snail

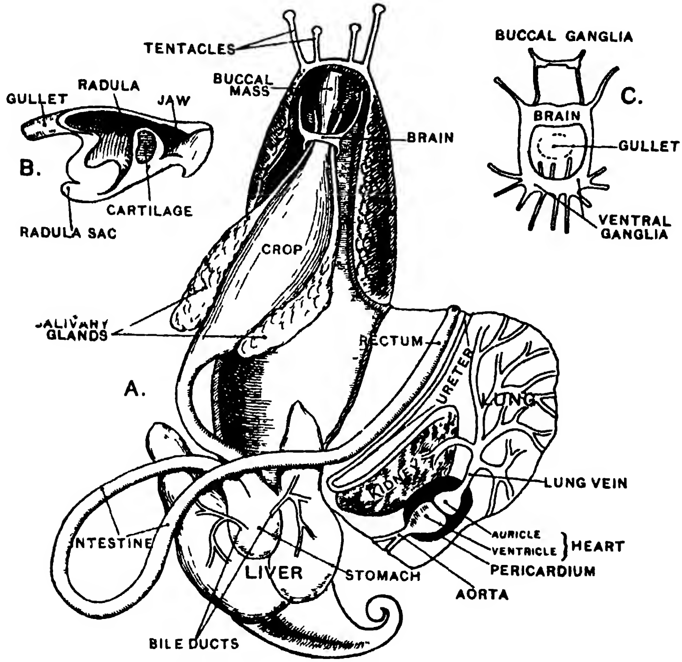


Fig 190 —Structure of Garden Snail (*Helix aspersa*)
A, General dissection, from upper side, roof of lung spread out to right B, Buccal mass, right half removed C, Nerve ring, from back.

remains in a torpid condition within its shell, or in other words *hibernates*, under which condition the want of operculum is compensated for by the formation of a limy partition across the mouth of the shell, leaving, however, a small aperture for breathing purposes.

As would be expected in a form so twisted, the *mantle-cavity* is in front, but no longer has a wide opening to the exterior, as this would lead to its delicate lining being dried up. There is, instead, a small aperture on the right-hand side, easily seen just within the margin of the shell. When the mantle-cavity is opened

no trace of a gill can be seen, but the thin *mantle* which forms its roof is raised up into a net-work of ridges traversed by blood-vessels and acting as a lung. The intestine runs down the right side of the mantle-cavity to its termination close by the lung-opening, and by its side runs the slender tube which carries off the waste matter from the single *kidney*, abutting against which is the pericardium containing a two-chambered *heart*.

The *nerve-ring* encircles the beginning of the gullet just behind the pharynx, and the nerve-loop is exceedingly short, and fused with it in such a way as to be exceedingly difficult to recognize. About 6000 species are included in the Pulmonata, and of these some 3500 belong to the same genus (*Helix*) as the Garden Snail. A much larger species than this is the Roman Snail (*Helix pomatia*), common abroad, and on the chalk downs of Kent and Surrey. It is said to have been introduced in Roman times for culinary purposes.

Land-Slugs may be regarded as derived from snail-like forms which have been more or less flattened out, and in which the shell is reduced or, it may be, absent altogether. Two common British species may be mentioned as examples, the small grey Field-Slug (*Limax agrestis*) with a reduced internal shell, and the much larger Black Slug (*Arion ater*) in which the shell is entirely absent.

The Pulmonate forms so far mentioned all agree in the possession of four tentacles, with eyes situated on the tips of the larger posterior ones. But there are still other forms in which only one pair of tentacles is present, at the bases of which the eyes are placed. Among these may be mentioned the Pond-Snail (*Limnæa stagnalis*) with a thin, pointed shell, and the Trumpet-Shell (*Planorbis corneus*), also an inhabitant of fresh water, and possessing a flat spiral shell.

CLASS 3.—BIVALVE MOLLUSCS (LAMELLIBRANCHIA)

The shell of a Gastropod, when it possesses one, always consists of one piece or valve, *i.e.* is *univalve*; but in the class now to be considered there is a *bivalve* shell consisting of a right and a left valve. The *Fresh-water Mussels*, abundant in many of our streams, canals, and ponds, furnish a convenient type. They belong to two genera, *Anodon* and *Unio*, which agree in

their main features, though there are certain differences, especially as regards the shell.

External Characters.—The animal is completely invested by the two elongated oval pieces which make up the shell, and are right and left respectively (fig. 191) They are united together above, along what is called the ***hinge-line***, and can either be brought close together elsewhere so as entirely to cover the soft parts, or may be separated so as to "gape" more or less, which is always the case in dead specimens. A series of closely-set lines following the curve of the shell can be seen on the outside, and it will be found that these "lines of growth", which mark successive additions of material, have as their centre a pointed projection near the straight upper edge of the valve, known as the ***beak*** or ***umbo.*** This clearly marks the oldest part, and, as in bivalves, usually projects forwards, and is nearer the front than the back end. When the shell is removed from the soft parts by cutting through certain muscles, it will be found that each valve covers a soft flap which lines it during life, and is really half the ***mantle*** (fig. 192), here clearly divided into right and left halves, which may be compared to the flaps of a man's coat, if the further assumption be made that the coat is a part of the body and its flaps are big enough to entirely cover the occupant.

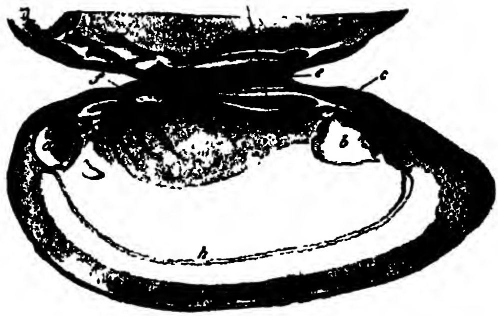


Fig 191.—Shells of Fresh-water Mussel (*Unio*), seen from within *a b*, Impressions of anterior and posterior adductors; *d f*, hinge-teeth; *e*, ligament, *h*, pallial line.

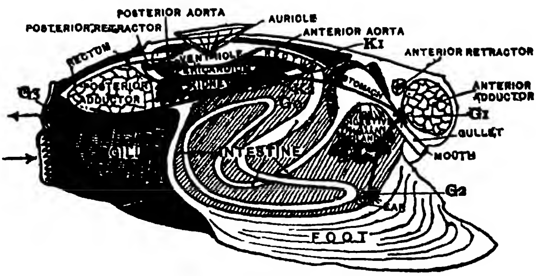


Fig 192 —Structure of Fresh-water Mussel (*Anodonta*)
G1-G3, ganglia: Go, opening of oviduct; K1 and K2, internal and external kidney-openings

Structure and Formation of the Shell.—The shell is a horny structure largely impregnated by salts of lime. It is produced by the underlying epidermis, from which a sticky substance exudes which afterwards becomes hard. In all classes of Molluscs the mantle has a great deal to do with the formation of the shell, but even here, where the mantle is very well developed, it does not line the part of the shell near the hinge-line, and yet that part can be repaired if broken. In a Garden Snail the mantle is of comparatively small extent, the chief part of it being the roof of the lung, yet all parts of the snail's shell can be repaired. The shell of the Mussel, and the same thing is true for a land- or sea-snail, consists of three layers: (1) a greenish external skin, often called incorrectly the epidermis; (2) a middle prismatic layer in which the calcareous material consists of oblique prisms; and (3) an internal pearly layer, made up of numerous thin lamellæ, the edges of which form a series of minute wavy ridges on the inner side of the shell, which are the agents to which the rainbow tints of the pearly layer are due. The edge of the mantle is thickened, and, both here and in most Mollusca, plays a very important part in the formation of the shell, the two outer layers originating from it alone. Repairs, therefore, except at the edge of the shell, are carried out in pearly material only, though further observations are wanted on the subject.

The two valves are united together in the region behind the umbo by a horny elastic band known as the *ligament*, which is kept on the stretch when the shell is closed. In the shell of Unio (fig. 191) there are projecting *teeth* along the inner side of the hinge-line in each valve, which fit into corresponding sockets in the other valve. Such teeth and sockets are entirely absent in Anodon, whence its name (Gk. *an*, without; *odous*, a tooth). The inner side presents a number of markings due to the attachment of muscles, and therefore called *muscular impressions*. The two largest of these are oval, and situated respectively near the front and back ends. They correspond (see fig. 192) to a couple of large muscles, the fibres of which run transversely across from valve to valve, and which, since their contraction serves to adduct or pull the valves together, are termed the anterior and posterior *adductor muscles* (L. *adduco*, I lead to). When they cease to contract, the elasticity of the stretched ligament comes into play

and pulls the shell open. Running from one adductor scar to the other is a curved *pallial line*, marking the attachment of the pallium or mantle to the shell. In a case like this, where the line is unbroken by any indentation, it is *integropalliate*, a point which will be referred to later when other bivalves are considered.

Both shell and contained animal are bilaterally symmetrical, a fact which is expressed as regarding the former by using the term equivalve. Each valve is in fact a mirror-image of the other, but in itself does not exhibit bilateral symmetry, *i.e.* is *inequilateral.*

The Mussel is in the habit of remaining obliquely buried in the mud with its hinder end projecting, and examination of an aquarium specimen in this position will show two openings, one above the other, between the mantle lobes (fig. 192). Water-currents continually set into the lower or *inhalent aperture*, serving the double purpose of carrying food to the mouth and oxygen to the breathing-organs, while other currents as constantly flow out of the upper or *exhalent aperture*, taking with them the various forms of waste matter. The inhalent aperture is fringed with sensitive tentacles, and if these are touched the shell at once closes, an arrangement which is obviously protective. The Mussel, therefore, is able to feed, breathe, and get rid of waste, with most of its body concealed from observation.

After removal of the shell (fig. 192) it will be found that the mantle-lobes are not united together except between the two apertures just described. If one of them be turned back other parts come into view, and the first thing to determine is which is front and which back end. A distinct head will be looked for in vain, and its absence is one of the characters of this class, which sometimes receive the name of "headless" Molluscs (*Acephala*, from Gk. *a*, without; *kephalon*, a head). This cannot be regarded as a primitive feature, and there is good reason to believe that the bivalves are descended from forms which possessed a distinct head, the dwindling of which has been brought about by a sluggish mode of life and dependence as regards food upon minute organisms brought to the mouth by water currents. The *mouth* will be seen in the Mussel as a wide slit just behind one of the adductor muscles, at the end further from the inhalent and exhalent apertures, which thus mark the hinder end of the animal. There is a complete absence of anything in the way of jaws, but a pair of soft leaf-shaped bodies,

the *labial palps*, may be seen on either side of the mouth. The body hangs down between the mantle-lobes, and its ventral part is modified into the orange-coloured *foot*, which, instead of presenting a creeping under surface, as in a snail, is flattened from side to side and projects forwards as a muscular body which has been variously compared, as regards its shape, to an axe or ploughshare. It can be protruded from between the valves of the shell, and serves as a pushing-organ, by which the animal can slowly plough its way through the mud with its front end first.

Very conspicuous are the plate-like *gills*, which have suggested the scientific name of the class (Lat. *lamella*, a plate; Gk. *branchia*, gills), and which are not only breathing-organs but are also largely concerned with setting up the currents of water which play such an important part in the life of the animal, being largely aided, however, in both these duties by the lobes of the mantle. The water-currents are a result of ciliary action (see p. 49). Each gill consists of an outer and an inner plate, and, despite its specialized form, has been produced by the modification of a gill-plume similar in kind to those found in the Ormer (see p. 308). The stem of the gill runs fairly parallel to the long axis of the body, and is attached to the body-wall above. The *mantle-cavity* is here the huge space between the mantle-lobes into which the gills and lower part of the body hang down, and, by the attachment of the former to adjacent parts, it is divided into a large lower section into which the inhalent aperture leads and a much narrower upper portion, above the gills, and communicating with the exterior by the exhalent aperture. This is most clearly seen behind the posterior adductor muscle, where the inner plate of one gill is seen to be fused along the middle line with the corresponding plate of the other gill, thus forming a partition between the upper and lower sections of the mantle-cavity.

Digestive Organs (fig. 192).—The most striking feature is a negative one, consisting in the entire absence of the characteristic rasping organ (odontophore) possessed by the other molluscan classes. It is believed that bivalves are descended from ancestors which were provided with this structure, which has been lost as a result of the same conditions which led to the dwindling of the head, and which have already been alluded to. The mouth leads into a short gullet, which opens into a stomach, that again continues into a coiled intestine, the last part of which runs up

to the dorsal side, traverses the heart (see below), and runs back over the posterior adductor to its termination in the upper section of the mantle-cavity.

Circulatory Organs (fig. 192).—The *heart*, situated in a pericardial cavity, has the dorsal situation characteristic of Invertebrates, and is essentially similar to the heart of the Ormer (see p. 308), consisting as it does of a central ventricle to which a thin-walled auricle is attached on either side. Purified blood is received by the auricles from the mantle-lobes and gills, and then passes into the ventricle, which distributes it to the body.

Respiratory and Excretory Organs (fig. 192).—As already mentioned, the function of breathing is carried out by mantle-lobes and gills. As to excretion of nitrogenous waste, this is effected by two elongated brown *kidneys* underlying the pericardium, with which they communicate on the one hand, while they open to the exterior on the other.

Nervous System and Sense Organs (fig. 192).—The ***central nervous system*** consists, as in the Ormer (see p. 310), of a nerve-ring and a nerve-loop. The former presents a ganglion on each side of the mouth (equivalent to one of the brain ganglia of the Ormer with a lateral ganglion fused with it) connected with one another above and with a pair of foot-ganglia embedded in the body close to the muscular foot. The nerve-loop is connected in front with the upper ganglia of the ring, and its posterior end lies just below the posterior adductor, where it is thickened into a pair of visceral ganglia. The three pairs of ganglia send out nerves to the parts of the body in their neighbourhood.

The Mussel undoubtedly possesses the sense of *touch*, especially as regards the edge of the mantle. It is also probable, though not absolutely certain, that it is endowed with *smell* and *taste*, and *water-testing organs* (osphradia) can be recognized near the visceral ganglia, though there is some doubt about their function, for they lie in the upper section of the mantle-cavity in the course of the outgoing currents of water, which is not in accordance with their supposed function. So-called ***organs of hearing*** are present, as in the Ormer (see p. 310), in the form of two little vesicles connected with the foot-ganglia and containing particles of carbonate of lime. They are probably concerned with the sense of equilibrium. Eyes are altogether absent.

Lamellibranchs are divided into five orders based on the

characters of the gills, and embrace between them some forty families. It will be enough for our present purpose to mention a few common species in illustration of the range of characters found within the class.

The *Cockle Family* includes a large number of shallow-water forms found along coasts and estuaries in most parts of the world. They are especially characteristic of places where sand is abundant. The best-known British form is the Edible Cockle (*Cardium edule*) of the Atlantic and Mediterranean areas. The shell is rounded in outline, and marked by prominent ribs which radiate from the beak. The edges of the mantle-lobes are much more extensively united than is the case with the Fresh-water Mussel, but an orifice is left in front through which the foot can be protruded, and at the back inhalent and exhalent apertures are seen as before, a striking difference being that they are here placed at the ends of two short tubes or *siphons*, both fringed by tentacles. The narrow bent *foot* is able not only to push the animal through the sand, but also by its sudden contraction to bring about springing movements in the water. The siphons can be drawn back within the shell by means of a special *retractor muscle*, and the attachment of this to the shell causes the pallial line to be indented at its posterior end, just as, to use a somewhat fanciful comparison that has been employed, a coast-line is broken by a bay or, to use the Latin word, *sinus*. By examination of the shell only we are therefore able to say in a given case (fig. 193) whether siphons of any size were present, the extent of the bay being roughly proportional to their development. This *sinupalliate* condition is contrasted with the integropalliate one described for the Mussel (p. 331), but it must not be forgotten that small siphons may be present devoid of muscles sufficiently powerful to indent the pallial line perceptibly.

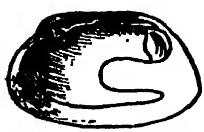


Fig 193.—Inside of right valve of a sinupalliate shell The bay (sinus) in the pallial line is seen on the right

The *Gaper Family* presents a certain amount of resemblance to the preceding as regards habit, and a common British form, the Sand Gaper (*Mya arenaria*) (fig. 194), is found both in mud and sand off many parts of our coast, and also on the opposite side of the North Atlantic. The thick oval shell is not ribbed like the Cockle, and the name "Gaper" has reference to the

fact that the valves cannot be brought together behind owing to the presence of enormous *siphons* that can only be drawn back into the shell to a limited extent. The two siphons are united into a single fleshy mass with two orifices at its tip, and protected by a brown wrinkled layer continuous with the outer horny layer of the shell. The protective arrangement suggested in the Mussel (see p. 331) is here carried to a much greater extent, for when the animal is buried in the mud, with only the tip of the siphon-tube projecting, it is singularly inconspicuous, though feeding and breathing can go on without interruption. The foot of the Gaper is small, and is of no use for springing.

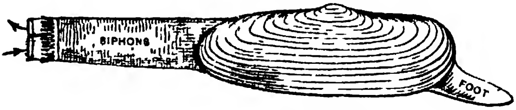


Fig 194 Sand Gaper (*Mya arenaria*)

Fig 195 —Razor Shell (*Solen*). Foot seen on left, siphons on right

A closely-related family is that of the *Razor-shells* (fig. 195), of which two British species are very common, *i.e. Solen siliqua* and *Solen ensis*. In both cases the shell is very long and narrow, and gapes at both ends, but in the former species it is straight and in the latter curved.

Some very interesting boring molluscs come fairly close in affinity to the Gapers. The *Rock-borers* (*Saxicava*) and *Piddocks* (*Pholas*) (fig. 196), both of which can excavate burrows in hard rock, include a number of British species belonging to two families, while a third family is represented in the Atlantic and Mediterranean by the so-called "Ship-worm" (*Teredo navalis*) that often completely riddles timber with its burrows, which are lined by a smooth shelly layer secreted by the surface of the long siphonal tubes.

All the preceding families belong to one, and that the largest, of the five orders of bivalves. We may take the *Sea Mussel Family* as representing another order, and of the forms included by far the most familiar, largely on account of its economic importance, is the Edible Mussel (*Mytilus edulis*) (fig. 197), of which vast numbers are found together attached to stones, wooden piles, or other firm objects, by means of strong blackish threads constituting the *byssus*. The dark bluish shell is somewhat wedge-

shaped, and the sharp beaks are placed at the extreme front end. There are no siphons, but merely two apertures, as in the Fresh-water Mussel, the inhalent one being very large and fringed. The small dark *foot*, though capable of being used as a locomotor organ, is not in constant employment as in free bivalves, which probably accounts for its relatively small size. The byssus arises from a deep pit behind the foot, and though it is commonly found

[illegible]

mooring the animal, it can be cast off if necessary, enabling the animal to creep away to some more desirable spot. The anterior adductor muscle is much smaller than the other, and this point is of special interest because it foreshadows cases where only the posterior adductor is present in the adult. This is a tendency to specialization, but the gills on the other hand are simpler in structure than those of a Fresh-water Mussel, for though they consist of two plates on each side, yet each of these can easily be broken up into distinct filaments. The gill is, in fact, a somewhat modified plume-gill in which the separate side-branches of the plume have not yet firmly united into plates, as in the fresh-water mussel.

The *Ark-Shells* constitute a family belonging to the same

order as the Marine Mussels, and agree with them in the character of the gills. The shell is somewhat rectangular in form, with a long hinge-line possessing many small similar teeth. The foot has a flattened under-surface, an exception to the general rule among bivalves. The group is represented by species in all parts of the world, and some of the individual species have a very wide distribution, as in the case of the British species *Arca lactea.*

In the *Scallop Family* we have represented a third order of bivalves which possess gills more complicated than those of Ark-Shells and Edible Mussels, but less so than in the Fresh-water Mussel and associated families. There are several

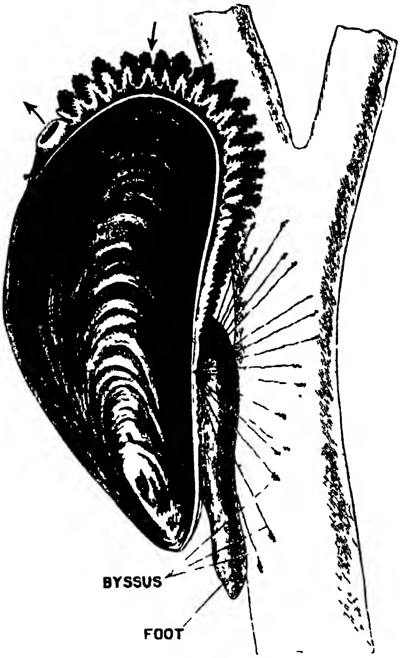


Fig. 197.—Edible Mussel (*Mytilus edulis*).

Fig. 198.—Pilgrim Scallop (*Pecten Jacobæus*).

species of British Scallops belonging to the genus *Pecten*, in which the shells are fan-shaped. The Pilgrim Scallop (*Pecten Jacobæus*) (fig. 198) is interesting as the source of the "cockle-shell" which the mediæval pilgrim to the Holy Land wore in his hat. Only one adductor muscle is present, the equivalent of the posterior one in the families so far mentioned. In some of the species the valves of the shell are equal according to the general rule, and in these the animal is able to swim by flapping them. In other cases, of which the edible Scallop commonly seen in fishmongers' shops furnishes an example, the animal is sedentary, and during life rests with its right valve below, this being well curved, while the upper or left valve forms a flat lid. A byssus is present,

serving to attach the creature to some firm object. There is in this genus an interesting variation on the mode of opening the shell described for the Fresh-water Mussel (see p. 330). There is no external ligament but what is called an ***internal ligament*** or cartilage, placed in a deep pit at the hinge and kept compressed when the shell is shut. When therefore the adductor muscle ceases to contract, the elasticity of this body will come into play, causing the shell to gape, just as a door might be made to fly open by the expansion of a piece of india-rubber shut into its hinge and thereby strongly compressed. The mantle-lobes of Pecten are quite free from one another, so that not only are siphons absent but also special inhalent and exhalent openings. The long plate-like *gills* follow the curve of the body, and water has ready access to them through the wide cleft between the mantle-lobes exposed when the animal opens its shell. The edge of the mantle is fringed by long tentacles, and bears quite a number of spherical eyes of a beautiful green colour. These have a very complicated structure, approaching in some respects to the eyes of Vertebrates.

The *Oyster Family* is closely allied to the preceding, but its members are still more modified. The shell is very irregular, and the animal is attached by the substance of the left valve, which in the Common Oyster (*Ostrea edulis*) of British seas is hollowed out while the right valve is lid-like, just the opposite to what is the case in a Scallop. The foot is entirely absent, and though the mantle-edges bear short tentacles, they are devoid of eyes.

Brief mention may be made of the *Nucula Family* as representing a comparatively small order of bivalves in which the gills present primitive characters. In the type genus *Nucula*, for example, the gill on each side is small and obviously like one of the gill-plumes of the Ormer, and a further primitive character is found in the possession of a foot with flattened creeping surface.

CLASS 4.—TUSK-SHELLS (SCAPHOPODA)

This small class includes the typical genus Dentalium and its allies. A British form, the Common Tusk-Shell (*Dentalium vulgare*) (fig. 199), may be taken as a type. It is found burrowing in the sandy parts of the sea-floor. The curved body is bilaterally

symmetrical, with the upper side concave, and it is covered by a tubular *shell* shaped something like an elephant's tusk, whence its name. This shell has an aperture at each end, the larger one being in front, and its formation may be understood if we suppose the presence of two long mantle-flaps which have fused together in the middle line below, and that shelly matter has been secreted continuously all round. This view is justified by the development. So far there would appear to be affinity with the bivalve molluscs, and this is confirmed by the shape of the *foot*—which, however, has a lobe each side as well as a central portion—and by the character of the *nervous system*. In other respects there is an approach to Gastropods, for though the head is much reduced it is not entirely absent, the mouth being placed on the end of a short non-retractile *proboscis*, behind which is a pharynx provided with the typical *rasping-organ*.

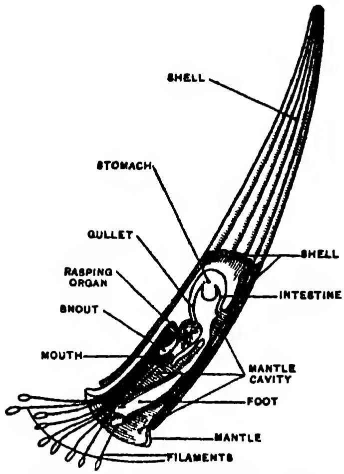


Fig 199.—Tusk shell (*Dentalium*) Shell partly removed

Springing from the base of the proboscis are two bunches of long filaments dilated at their ends, and capable of protrusion for some distance from the mouth of the shell. These are supposed to be of use in capturing small organisms as food, and it is possible that they represent the gills of other forms, though this is by no means certain.

CLASS 5.—PROTO-MOLLUSCS (AMPHINEURA)

The different classes of Molluscs are all supposed to have sprung from bilaterally symmetrical forms with fairly distinct head, a rasping-organ, and a creeping foot. There was probably a continuous mantle-flap sheltering in the hinder-part of the body a pair of plume-like gills, near which would open the paired kidneys, one on each side of the intestinal aperture. The heart would be dorsal and posterior in position, and would most likely consist of a muscular ventricle with a thin-walled auricle on each

side. From creatures of this kind we can imagine Cephalopods, Gastropods, Lamellibranchs, and Scaphopods derived by specialization along different lines, the nature of which has been already indicated in the description of these classes. The small number of forms which make up the present class have probably retained to a higher degree than any other living forms the characters

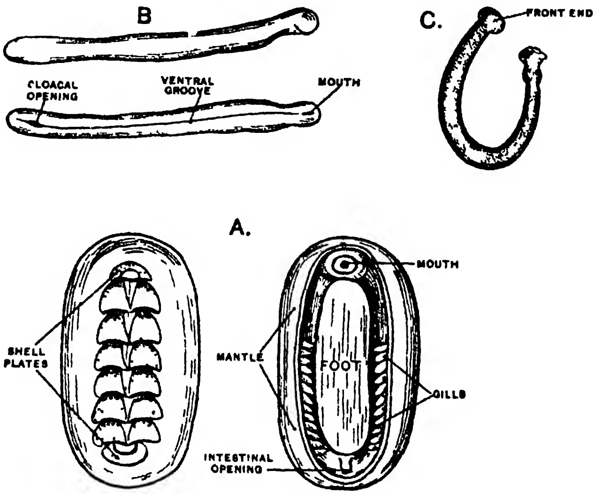


Fig. 200.—Proto-molluscs

A, Mail Shell (*Chiton*), seen from above and below. B, Proneomenia, right side and under surface. C, Chætoderma.

of these hypothetical ancestors, though they also have undergone modifications of their own, and it is often a difficult problem to determine which of their characteristics are primitive and which not.

The most abundant and familiar of these animals are the *Mail-Shells* or *Chitons* (fig. 200), most of which live under stones near low-water mark. A common British form is *Chiton marginatus.* In the bilateral symmetry, the presence of a fairly well-marked *head*, a broad, creeping *foot*, and a continuous *mantle-flap*, the Chitons are probably primitive. The same thing may be said regarding the dorsal *heart*, which is placed posteriorly and possesses the three typical chambers, and the *kidneys*, which are paired and open far back. The *rasping-organ*, however, is highly complex, and the *gills* are arranged in a row on each side, instead of being two in number. Quite possibly, however, the many-

gilled is more primitive than the two-gilled condition, and there are some Chitons which have a limited number of gills far back on each side. As to the *shell*, we find eight overlapping plates situated on the dorsal side.

The remaining Proto-molluscs (fig. 200) are unfamiliar marine forms inhabiting moderately or very deep water. They possess no *shell*, but the skin is beset with calcareous spicules, and they are more or less worm-like in appearance. The *foot* is either a narrow ridge placed in a longitudinal groove (*Neomenia*, *Proneomenia*), or may be entirely absent (*Chætoderma*). There is a small posterior *mantle-cavity* into which the intestine and paired kidneys open, while it may shelter a pair of plume-like *gills* (*Chætoderma*), or these may be represented by a tuft of filaments (*Neomenia*) or merely by folds (*Proneomenia*). Though at first sight the view is tempting that these genera are more primitive than Chiton, and give an indication of how Molluscs might arise from worm-like forms, it is more probable that they are simplified animals which have lost some of the typical molluscan characters, and are, so to speak, going downhill rather than uphill.

CHAPTER VIII

STRUCTURE AND CLASSIFICATION OF JOINTED-LIMBED ANIMALS (ARTHROPODA)

This is by far the largest of the great groups of the animal kingdom, including, as it does, Insects; Scorpions, Spiders, and Mites; Centipedes and Millipedes; Lobsters, Crabs, Shrimps, and a host of other Crustacea.

The Lobster, a typical member of the phylum, has already been briefly described in illustration of the characters of the higher Invertebrates (see pp. 302–304). It may be convenient to point out the respects in which it is typical of the group Arthropoda. These are: *bilateral symmetry*, the division of the body into a series of *segments* grouped into regions and bearing a series of paired *jointed limbs*, and the presence of a central nervous system consisting of a *nerve-ring* and a *ventral cord*. It may also be noted that the so-called *body-cavity* consists of a set of blood-containing spaces situated between the internal organs and the wall of the body. They form, therefore, a part of the blood-system, while the body-cavity of a Vertebrate (see p. 42) belongs to the lymph-system. Molluscs agree with Arthropods in this respect, except that in them the pericardial cavity does not contain blood, but is comparable to the corresponding cavity in a Vertebrate so far as that particular feature is concerned. In Arthropods, however, the heart is situated in a blood-containing space from which blood passes into it.

The phylum is divided into the following classes, which will be considered in the same order:—

A.—Air-breathing Forms (Tracheata).

Class 1. Insects (INSECTA).
Class 2. Spider-like Animals (ARACHNIDA).—Scorpions, Spiders, Mites
Class 3. Centipedes and Millipedes (MYRIAPODA).
Class 4. Peripatus (PROTOTRACHEATA).

B.—Aquatic Forms (Branchiata).

Class 5. Crustaceans (CRUSTACEA).—Lobsters, Crabs, Shrimps, &c.
Class 6. King-Crabs (XIPHOSURA).
Class 7. Sea-Spiders (PYCNOGONIDA).

A.—AIR-BREATHING ARTHROPODS (TRACHEATA)

CLASS I.—INSECTS (INSECTA)

This class embraces an astonishing number of species, more numerous, in fact, than those of all other groups of land animals put together. Yet, in spite of this, they do not exhibit so wide a range of characters as might be expected, so that the study of a carefully-chosen type forms an intelligible key to the entire class. The too-familiar Cockroach or Black "Beetle" (*Periplaneta orientalis*) furnishes just such a type, though the American species (*P. Americana*) obtainable in many seaports, is decidedly better on account of its larger size.

External Characters (fig. 201).—The body is obviously divided into three regions—head, thorax, and abdomen—the distinction between the first two being emphasized by the presence of a narrow neck. In such an insect as a wasp the demarcation between thorax and abdomen is equally sharp, while in many insects, on the other hand, the three regions are bounded by a continuous curved outline unbroken by constrictions.

Each one of these three regions of the body is made up of rings or *segments*, which differ very much among themselves in character, and in some places are so closely fused together that their exact number cannot be definitely made out. Arthropods, in fact, or any large group of them, furnish innumerable instances of the phenomena described elsewhere (see p. 195) in reference to the skeleton of the limbs, where all sorts of modification of a common plan may arise by unequal development of parts, fusion, and reduction. One of the lower Arthropods, for example, such as a Centipede or Peripatus, consists of a large number of similar segments which have only undergone great specialization at the head end, while in such highly specialized forms as Insects the segments have been much reduced in number, and are grouped into regions which, in correspondence with special uses, have acquired special characters.

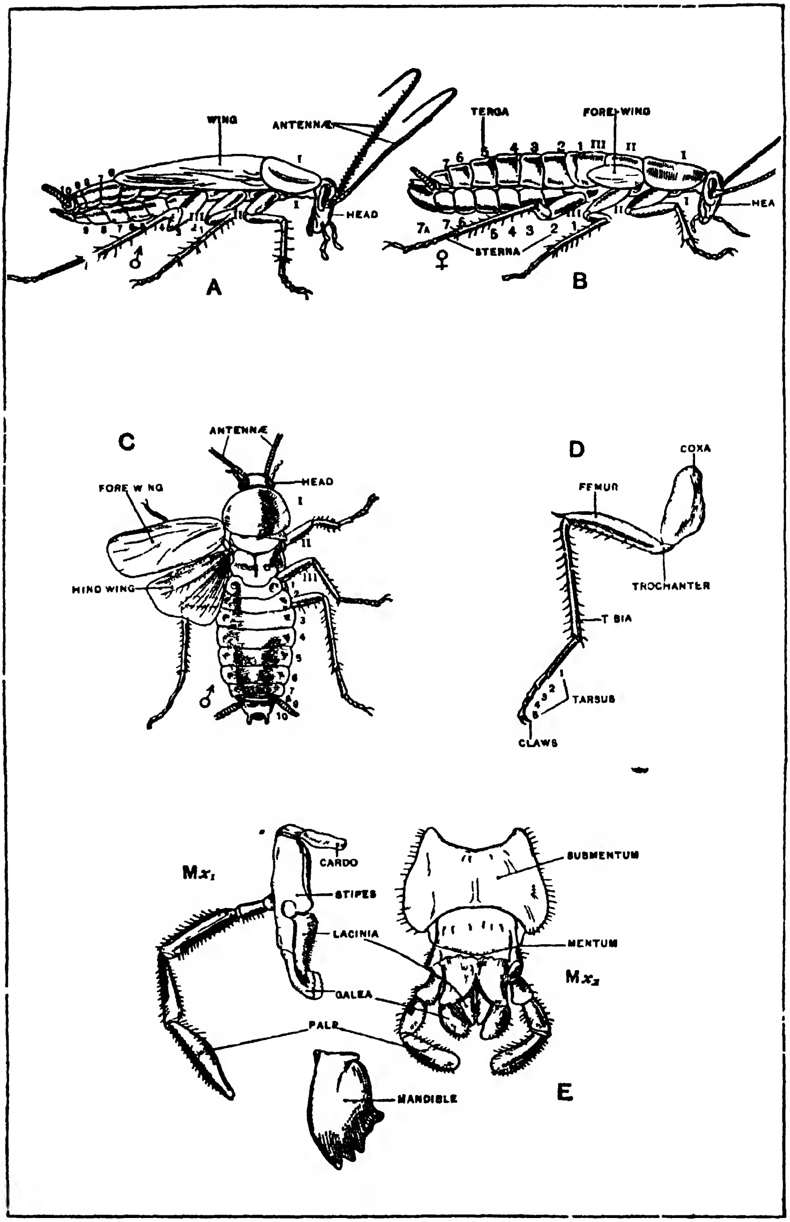


Fig 201 —External Characters of Cockroach (*Periplaneta orientalis*)

A, B, C, Side views of male and female and top view of male I, II III, segments of thorax 1–10, segments of abdomen D, A leg (enlarged) E, Jaws much enlarged) Mx_1, First maxilla Mx_2 second maxilla

Among Insects the Cockroach is a fairly central type, and the least modified part of it is the *abdomen*, in which ten segments can clearly be distinguished. A pair of flattened jointed rods, the *cerci*, spring from the last segment, and are probably to be regarded as limbs, which are otherwise absent in this region, if certain doubtful structures be excepted. This practically limbless condition of the abdomen is characteristic of insects, and has been brought about by reduction. The *thorax* is commonly regarded as made up of three segments, and each of these bears a pair of jointed limbs or appendages in the shape of *walking-legs*. Each leg is composed of several pieces (10) movably jointed together, a character which is common to all Arthropod limbs, and has given the name to the phylum (Gk. *arthros*, jointed; *pous*, a foot). The parts of the leg differ much among themselves in respect of size and shape. The thorax also bears a pair of flattened expansions, forming the wings, attached to its second and third segments, which in the male of the common Cockroach, and both sexes in the American species, extend far backwards and overlap the abdomen. The fore-wings are horny structures, and may be termed the *wing-covers*, since they cover and protect the delicate membranous hind-wings, or wings proper. In the female of the ordinary Cockroach the fore-wings are very small and the hind-wings absent, reduction having taken place in both cases.

The *head* consists of a number of segments which have fused so intimately together that the boundaries between them cannot be made out. As, however, in the higher Arthropods the presence of pairs of jointed limbs is taken to indicate the existence of a corresponding number of segments, a certain clue is afforded, though, as all segments do not bear limbs, such evidence is only partial. In this case, as in Insects generally, there are four pairs of appendages, so that the head possesses at least four segments. The first of these are two slender jointed feelers or *antennæ*, serving as organs of touch, and probably also having to do with other senses. The remaining appendages are three pairs of jaws, named, from before backwards, mandibles, first maxillæ, and second maxillæ. As in all Invertebrates they are quite outside the opening of the mouth, and those of them which are used for biting work from side to side. Each *mandible* consists of a single broad horny piece, toothed on its inner edge,

where it bites against its fellow. The *first maxilla* on either side has a two-jointed stalk, upon the end of which are borne a slender outer and a shorter inner branch. The former is made up of a number of narrow joints, and is known as a *palp*, while the inner branch consists of two parts, a cutting blade next the middle line and a soft piece adjacent to the palp. The smaller *second maxillæ* are built on the same lines, but are fused together to form what is commonly called the "under lip" or *labium*. It is the united stalks which have so fused, and though these particular appendages are considered as jaws, the union has of course taken away any power of biting against each other. Projecting from the front of the mouth is a broad horny plate, the "upper lip" or *labrum*, and in the narrow space between this and the labium the mandibles and cutting parts of the first maxillæ work against one another. The Cockroach is clearly an example of Insects with biting mouth-parts, but in other cases we find the corresponding appendages adapted to very different uses, furnishing one of the best examples known of modifications of a common type.

A large kidney-shaped *eye* will be seen on each side of the head, and a good lens will show that each of these possesses a large number of six-sided facets. An eye like this is generally known as a "compound eye", each of the facets having been formerly regarded as equivalent to an independent simple eye. Some of the other external characters are mentioned elsewhere.

Skin and Exoskeleton.—The body is invested in a strong horny covering secreted by the underlying epidermis. Movement is rendered possible by the presence of softer areas between the firmer tracts, so that the head is not immovably fixed, the segments of the abdomen can move one upon the other, and the joints of the limbs can be bent in various directions. In fact the same problem has had to be solved as that involved in the construction of a suit of armour, *i.e.* the combination of efficient protecting power without undue sacrifice of flexibility. It is of especial importance to notice that the narrow side of the body is for the most part provided with a softer investment than the broad upper and lower surfaces.

Digestive Organs (fig. 202).—The head of the Cockroach is bent downwards at right angles to the long axis of the body, so that the mouth-opening at its end faces downwards. It leads

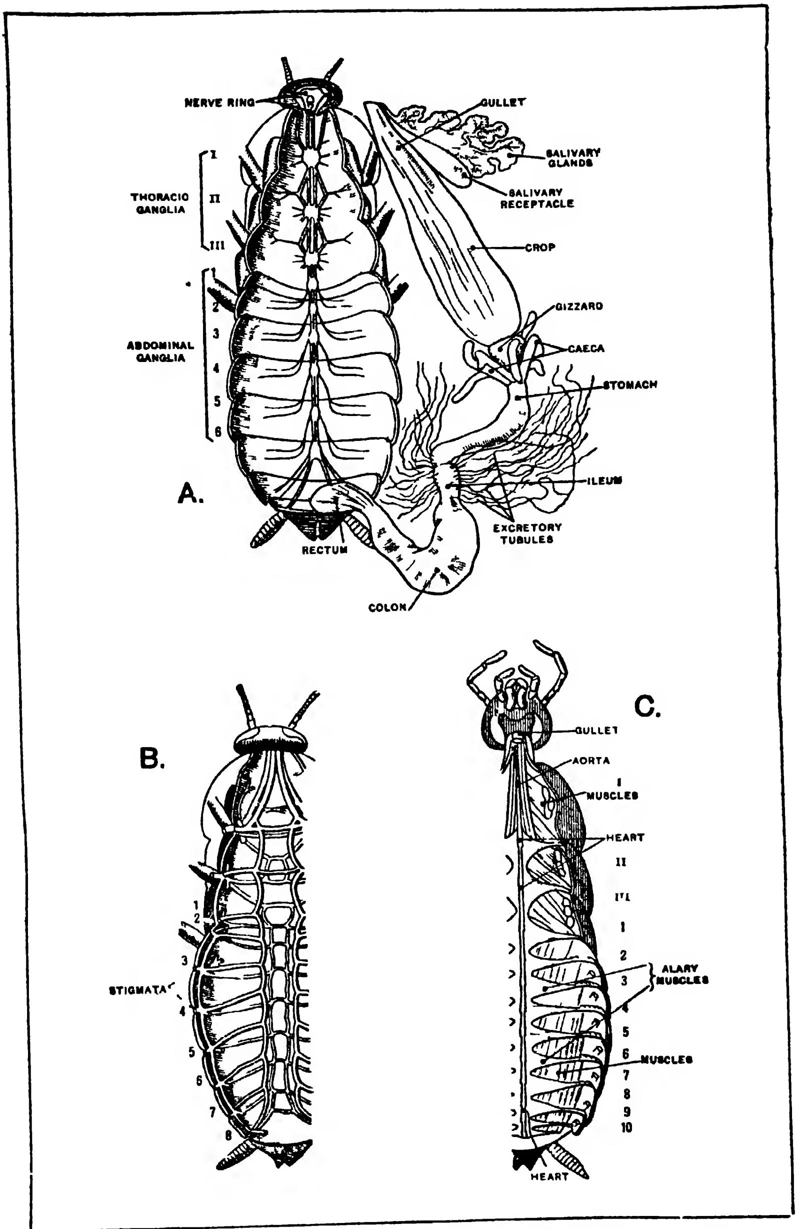


Fig 202 —Structure of Cockroach (*Periplaneta orientalis*) (enlarged)
A, Digestive organs and nervous system B Air tubes (tracheæ) C, Heart and muscles I-III, Segments of thorax 1-10 segments of abdomen

into a small *mouth-cavity*, from the back of which projects a pointed *tongue*, and which passes into a narrow *gullet* continuous with a large thin-walled *crop*, and that again with a smaller thick-walled *gizzard*, from which a fairly long *intestine* runs to its termination between the cerci. The gizzard is provided with an internal chewing arrangement, such as is not uncommon among Arthropods. It consists of a firm lining raised into horny teeth and bristly ridges. Digestive fluids are poured into the digestive tube by a pair of branching *salivary glands* which open into the mouth-cavity, and a number of club-shaped "*liver*" *tubes* (digestive cæca) which encircle the beginning of the intestine.

Circulatory Organs (fig. 202).—This is not very highly specialized, for a reason to be mentioned later. The whole of the body is traversed by irregular blood-spaces of various sizes, but the only definite tubular structure is the *heart*, a long narrow blood-vessel running through the thorax and abdomen close to the upper surface. Along its sides are numerous pairs of valvular openings, through which blood passes in from the surrounding blood-space (pericardial sinus) to be pumped forwards. The heart is systemic, as it contains pure blood.

Respiratory Organs (fig. 202).—These organs present a very interesting and remarkable arrangement, for instead of the impure blood being sent to a localized lung for purification, air is conveyed to all parts of the body by means of branching *tracheal tubes*. These communicate with the exterior by means of ten pairs of small openings or *stigmata* on the sides of the body, all but the first two pairs being in the abdomen. Observation of a living Cockroach will show that the abdomen alternately dilates and contracts, the result being that air is drawn into and expelled from the stigmata. It is therefore possible to choke an insect by smearing the sides of the body with oil or some other substance which will block up these openings. The tracheal tubes appear silvery under the microscope, owing to the air which they contain, and they are lined by an elastic membrane thickened into a continuous spiral thread, so as to render them very flexible and non-collapsible. Just within each spiracle is a kind of valve, formed as a projection of the lining membrane and helping to prevent the intrusion of foreign particles.

As a result of this very thorough system of aeration, the blood

never has the opportunity of remaining impure, a fact which accounts to some extent for the imperfect condition of the circulatory organs. The restless activity of insects, and their great muscular powers, are also no doubt related to the unusually perfect state of the breathing apparatus.

Excretory Organs.—These also are very unlike anything so far described in the animal groups reviewed. They consist of a large number of very slender *Malpighian tubes*, which open into the intestine not far from its commencement.

Nervous System and Sense Organs (fig. 202).—The *nervous system* consists of a narrow and much-thickened *nerve-ring* closely encircling the gullet, and of a ventral double *nerve-cord*. The upper part of the ring is formed by a pair of large brain-ganglia, sending nerves to the eyes and antennæ, while its lower part is made up of another pair of ganglia, supplying the upper lip and three pairs of jaws. The ventral cord dilates within the thorax into three pairs of ganglia which innervate the three thoracic segments, and within the abdomen into six smaller pairs of ganglia, of which the first five belong to the corresponding abdominal segments, while the last and largest pair provide for the nerve-supply of the last five segments. Segmentation of the body as exhibited by Vertebrates, Arthropods, and some other phyla of the animal kingdom, means the existence of a number of successive rings or segments, containing sections of the various internal organs. Where the segmentation is very well marked, many structures are affected by it, and the more primitive the animal the more closely do the segments resemble one another. As regards the nervous system of Arthropods, there can be no doubt that the simplest condition is found in the presence of a distinct pair of ganglia for each segment, but Insects especially present considerable modifications of this primitive arrangement. Where a segment is relatively large, its ganglia will be so too, as seen in the thorax of the Cockroach, while fusion of segments will be accompanied by fusion of ganglia, as in the case of the jaw-bearing segments. The ganglia, further, may be among the first parts to fuse together, as seen in the last pair of the abdominal chain in the Cockroach, which represent the ganglia for the last five segments all united together, though the segments themselves are still more or less distinct.

The chief *sense organs* are those of *touch*—including the

antennæ, maxillary palps, labial palps, and cerci—and those of *vision*, as represented by the large compound eyes. There is good reason to believe that the antennæ are organs of *smell* as well as of touch, and it is probable that some of the mouth parts, perhaps the second maxillæ, have to do with *taste*. It may be further remarked that great difficulty attaches to the interpretation of many of the sense organs possessed by animals (see p. 264), and Insects, among others, are undoubtedly endowed with special senses of which it is difficult, if not impossible, for us to form any idea, our only definite standards being our own sense organs, which are those of much specialized land animals. In a subsequent chapter this interesting subject will be more fully discussed.

Life-history.—An insect such as a Butterfly or Moth goes through widely different stages in its life-history Hatching from the egg as a caterpillar, it grows to a considerable size, and then becomes a motionless chrysalis, from which the adult insect later on escapes, its body having been formed by a series of revolutionary changes from the substance of the chrysalis body. This life-history, familiar to all who have kept silkworms, and furnishing a useful metaphor to moralists of all centuries, is one which exhibits complete change of form, or *metamorphosis*, to use the technical expression. The life-history of the Frog (see p. 254) is an example of the same kind of thing, the essence of which consists in considerable modification in form and structure after the animal has been hatched out and has started a free independent existence Insects differ very much among themselves as to the amount of metamorphosis, and the Cockroach exemplifies an order in which it is so slight as to be practically absent. The eggs are laid in horny capsules, each containing sixteen, and the just-hatched Cockroach closely resembles the adult, from which it chiefly differs in its smaller size and the absence of wings. As growth proceeds, the firm exoskeleton is not increased in size to suit the enlarging body as in a Mollusc, but is bodily thrown off or "moulted", a very common phenomenon among Arthropods. After some seven moults the adult size is attained.

Classification of Insects.—Considering that some 250,000 distinct species have been described, and that at least ten times this number are believed to exist, it will be realized that the classification of insects is likely to present some difficulties, espe-

cially as there are not the same obvious distinctions as are found in some other groups, *e.g.* Molluscs. Various subdivisions have been proposed, some of the modern ones being complex, but it will be the simplest plan to adopt here the comparatively old-fashioned grouping into nine orders, primarily based upon the characters of the wings, and which is mainly due to Linnæus. It will be enough for the present purpose if some of the commonest insects are mentioned, and sufficient detail given to enable the reader to refer an insect to its proper order.

Order 1. Bugs (HEMIPTERA).—Four wings, of which the front pair are often only membranous at the tips.

Order 2. Fringe-winged Insects (THYSANOPTERA).—Four wings, all very narrow and fringed.

Order 3. Flies (DIPTERA).—A single pair of membranous wings equivalent to the front pair of other insects.

Order 4. Moths and Butterflies (LEPIDOPTERA).—Four wings present, covered with scales.

Order 5. Beetles (COLEOPTERA).—Four wings, of which the front ones are converted into hard wing-cases, covering the membranous hind-wings, which during repose are folded transversely.

Order 6. Membrane-winged Insects (HYMENOPTERA). — Four membranous wings possessing but few nervures, and which cannot be folded up. Fore-wing larger than the hind.

Order 7. Net-winged Insects (NEUROPTERA). — Four membranous wings, with an elaborate net-work of nervures.

Order 8. Straight-winged Insects (ORTHOPTERA).—Four wings, of which the front pair are horny wing-cases, while the others are membranous and fold up in a fan-like manner when at rest.

Order 9. Wingless Insects (APTERA). — Primitive wingless insects. Insects belonging to other orders may have lost their wings by a process of reduction affecting one or both sexes.

Order 1.—BUGS (Hemiptera)

The English name given to the order is somewhat libellous, for though a number of repulsive forms are included here, others again are beautifully coloured and attractive objects. A typical species is outlined in fig. 203. There is considerable variation in the matter of *wings*, as both pairs may be much alike, or the fore-wings may be wing-cases, or again both pairs may be absent. In all cases the mouth-parts are converted into piercing and sucking organs, which, though much unlike the corresponding

parts of the Cockroach both in appearance and use, can be compared with them part for part. The narrow *upper lip* is pointed, and below it are the *mandibles*, but these, instead of being cutting-jaws, are long piercing stylets, grooved along their inner sides in such a way as, when applied together, to form a double tube down the lower half of which saliva can pass to the object pierced, while juices can travel along its upper half to the mouth. Outside, and close to the mandibles, are the *first maxillæ* in the form of two more stylets devoid of palps. The four stylets to-

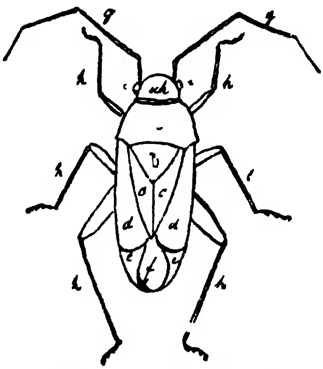


Fig. 203.—A typical Bug (*Capsus*). *a*, *b*, First two segments of thorax; *c*, *d*, horny part of wing-covers; *e*, *f*, membranous part of wing-covers; *g*, antennæ; *h*, *h*, *h*, legs; *i*, eyes; *sch*, top of head.

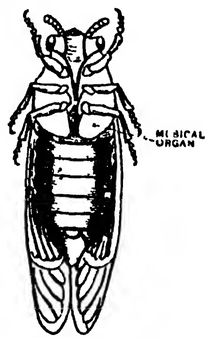


Fig. 204.—Cicada, seen from below.

gether constitute an efficient piercing organ which can be protruded or drawn back at will by the action of special muscles, and it also forms a channel along which fluids can be conducted to the mouth, as just explained. The *second maxillæ*, including their palps, are fused together into a sheath for the piercing mouth-parts. In most cases the adult condition is attained without any large amount of metamorphosis.

The order is conveniently divided into two sub-orders; *i.e.* 1. Homoptera, in which the two pairs of wings are similar; and 2. Heteroptera, in which they are unlike.

1. *Homoptera.* — These all live upon the juices of plants, and their fore-wings are of uniform texture. *Cicadas* (fig. 204) are large, broad insects with membranous wings of considerable size, which may be opaque and brightly coloured. The antennæ are very small, and the head not only bears large lateral eyes, but also three simple eyes or *ocelli* placed in front and often gem-

like in appearance. The males are provided with musical organs on the under-side of the thorax, by which they are enabled to make a chirping sound, the well-known "song of the Cicada". The eggs are deposited in the branches of trees by means of a piercing organ with which the tail of the female is provided, and from them are hatched wingless larvæ, which dig into the ground by means of their fore-legs and subsist on the juices of roots, ultimately making their way up again and becoming adult. The larvæ may remain as such for a long period, in one North American species for seventeen years. Cicadas, of which there are very numerous species, inhabit the warmer parts of the earth, some of them being natives of South Europe.

Lantern-Flies and their allies make up a closely-related family, many members of which are beautifully coloured, but the species found in Europe (including Britain) are not highly endowed in this respect. The name "lantern-fly" has not been so far justified.

Most persons have seen, during the summer months, those frothy masses on plants to which the name "cuckoo spit" is vulgarly given. These enclose the larvæ of small insects belonging to this sub-order, and known as *Frog-Hoppers* on account of their leaping powers.

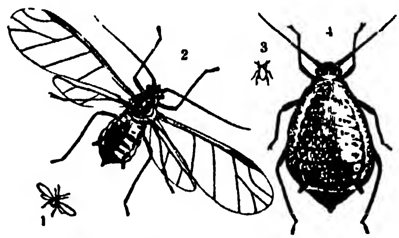


Fig 205 —Cabbage Aphis (*Aphis brassicæ*)
1, 2, Male (natural size and enlarged), 3, 4, female (natural size and enlarged)

Plant-Lice, or *Green-Flies*, furnish other examples (fig. 205). The best-known forms are the little green aphides common on geraniums and other garden plants, and which, like their immediate allies, are distinguished by a complex life-history. The Vine-Louse (*Phylloxera vastatrix*) is a creature of the kind which does immense damage in vineyards.

The Cochineal Insect (*Coccus cacti*), on the other hand, is of economic importance. It is a native of Mexico and Central America, where it feeds upon cacti.

Heteroptera.—To the insects of this sub-order the name "bug" is properly applied. When wings are present, the front pair are transformed into wing-covers, the tips of which, however, remain membranous. Many of the species are distinguished by

a disagreeable odour, due to the secretion of certain glands which open on the under-side of the third segment of the thorax. Some are terrestrial and others aquatic. Many of the land bugs are not among the personal enemies of man, but feed on the juices of plants. These forms mostly escape the observation of those who are not entomologists, but the wingless blood-sucking bed-bug (*Cimex lectularius*) has an effective way of compelling attention that has rendered it the most widely known among its order. Even more odious are the small wingless forms known as *lice* which infest the bodies of human beings and many other animals, multiplying with astonishing rapidity. They are regarded as bugs which have become degenerate as a result of their parasitic habit. A typical example is the Head-Louse (*Pediculus capitis*), which feeds on the blood of the scalp, and lays its eggs on the hairs, to which they are firmly attached.

The *water-bugs* comprise a number of forms familiar to the student of fresh-water life, and to some extent known even to the casual observer. The *skaters*, which are often seen gliding about on the surface of the water, are of this kind, or, to speak more accurately, constitute a family allied both to land- and water-bugs. The Needle-Bug (*Limnobates stagnorum*), with long attenuated body and deliberate movements, is conspicuous among them. The Pond-Skater (*Gerris paludum*) has a stouter body and moves very rapidly. One genus (*Halobates*) is especially interesting in being a marine form living upon the surface of the sea even at great distances from land. This is remarkable, for though insects are exceedingly dominant as terrestrial forms, and are far from uncommon in fresh water, they are almost unrepresented in the marine fauna.

Water-bugs proper are inconspicuous insects distinguishable from their terrestrial allies by their extremely-reduced antennæ, and by the fact that they actually live in the water and not merely on it like the skaters. The *Water-Scorpions* are rapacious narrow-headed forms, in which the fore-legs are used for seizing their prey. The narrow tail-like prolongation which has suggested the common name is an arrangement connected with breathing, as will elsewhere be described. In some species there is a broad flat body (*e.g. Nepa cinerea*), while in others it is long and narrow (*Ranatra linearis*). Equally common are the broad-bodied *Water-Boatmen* (*Notonecta*), which, by means of their long hair-

fringed hind-legs, row themselves along upon their backs. Like the forms already mentioned, they prey upon small flies and the like.

Order 2.—Fringe-winged Insects (Thysanoptera)

This is a very restricted order, including minute insects with suctorial mouth, long narrow body, well-developed slender antennæ, and four narrow wings with a fringe of hairs. The male is wingless. There is also a peculiarity about the feet, which end in bladder-like lobes.

Fig. 206.—Corn Thrips (*Thrips cerealium*), 1, 2, female walking; 3, 4, female flying. Potato Thrips (*Thrips minutissima*), 5, 6, larva, 7, 8, female flying. 2, 3, 5, 7, natural size; 1, 4, 6, 8, enlarged.

Some of the species infest flowers, *e.g.* those of Elder; and the Corn Thrips (*Thrips cerealium*) (fig. 206) does a good deal of damage to crops.

Order 3.—Flies (Diptera)

This is one of the largest orders of Insects, and includes not only innumerable *Flies*, but also those modified forms which are known as *Fleas*. As the scientific name indicates (Gk. *dis*, twice; *pteron*, a wing), only two wings are present (fig. 207). These are membranous, with comparatively few nervures, most of which run longitudinally, and they correspond to the fore-wings of other Insects. The hind-wings, however, have not entirely disappeared, but are represented by two club-shaped vestiges, which from their function are known as *balancers* (*halteres*).

The *mouth-parts* (fig. 207) are adapted for sucking, and often for piercing as well, but there are considerable differences from the arrangements which serve similar purposes in the Hemiptera. These structures are best developed in the females of such forms as Gnats, Mosquitoes, and Gad-Flies, where mandibles, maxillæ, and tongue are in the form of five piercing stylets, ensheathed in an imperfect tube formed by the labium and partly covered over by the long sharp labrum. Maxillary palps can be seen at the base of the proboscis. In the males of these forms, and both sexes of some members of the group, *e.g.* House-Fly (*Musca*

domestica), the piercing parts are much reduced and the mouth is purely suctorial.

Diptera undergo a complete *metamorphosis*. From the egg a limbless *larva* (maggot) is hatched, which becomes a *pupa*,

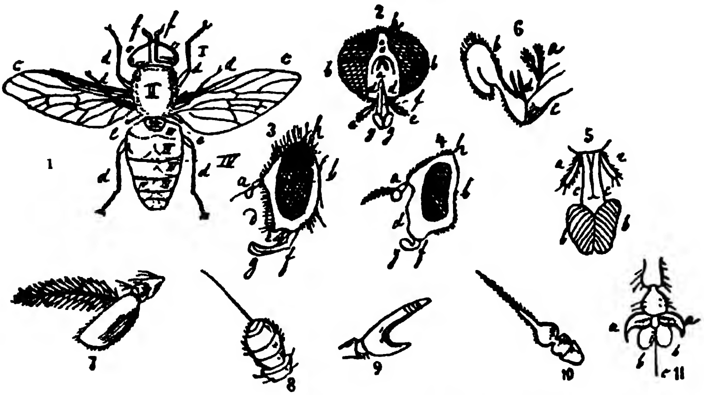


Fig. 207.—Structure of Flies (*Diptera*), enlarged to various scales.

1, Parts of body: I, head; *o, o*, eyes; *f, f*, antennæ; II and III, thorax; *c, c*, wings; *e, e*, balancers; *d, d, d*, legs; IV, abdomen, with segments indicated. 2, Head (front view): *a*, antennæ; *b, b*, eyes; *c*, forehead; *d, d*, upper lip; *e, e*, palps; *f*, body of proboscis; *g, g*, suctorial flaps of proboscis. 3, 4, Head (side view): *a*, antennæ; *b*, eyes; *d*, lower part of face; *e*, palp; *f*, proboscis; *g*, suctorial flaps of proboscis; *h*, crown of head. 5, Proboscis (front view): *a, a*, palps; *b, b*, suctorial flaps; *c, c*, stalk. 6, Proboscis (side view): *a*, palps; *b*, suctorial flaps; *c*, stalk; *d*, mandibles. 7–10, Antennæ of various flies. 11, Foot: *a, a*, claws; *b, b*, adhesive lappets; *c*, bristles.

that may or may not possess the power of movement, and from which the adult insect or *imago* is developed. As the adult does not grow in size, the various-sized Flies which are often to be seen on windows and elsewhere are different species, and not, as often supposed, different stages in the growth of the same species.

Fig. 208.—Common Gnat (*Culex pipiens*), much enlarged.

The Common Gnat (*Culex pipiens*) (fig. 208) is a representative of a very large family in which the females are distinguished by their blood-sucking propensities, while the males are supposed to live upon the juices of plants. The body is slender, the legs long, and the antennæ are well-developed, those of the male being beautiful plume-like objects. The eggs are laid on the surface of ponds, &c., a considerable number being agglutinated together

into a sort of raft. The *larvæ* which hatch out from them (fig. 209) look something like little red worms with large heads, and they possess a special breathing arrangement in the form of two tubes, each with a stigma at its tip, projecting from the hinder end of the body. The favourite position of the larva is suspended head downwards close to the surface, with the ends of these tubes just projecting above water, and so enabling breathing to

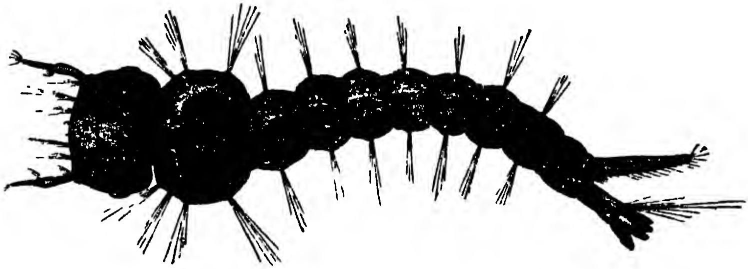


Fig. 209.—Larva of Common Gnat (*Culex pipiens*), greatly enlarged

be carried on. After several moults, the larva becomes a *pupa*, at the front end of which the wings, legs, and antennæ of the adult can be dimly made out under the skin. From each side of the thorax a breathing-tube projects, and these are used like those of the larva, except that owing to their position the animal is suspended tail downwards. The pupa is active, and swims by jerking its tail. Examination from time to time of almost any old rain-water butt will enable one to trace the successive stages of the life-history of the Gnat, the final one of which is reached by the splitting of the pupal skin down the middle of the back, making a rent from which the adult Gnat makes its exit, being floated up meanwhile by the buoyancy of its investments.

Midges resemble Gnats in many particulars, and pass through a somewhat similar life-history; but they are much smaller, and it is only the females of some species which possess mouth-parts adapted for blood-sucking. The small black Midge (*Ceratopogon*) which is so troublesome in the summer months is one of these forms. The Plumed Midge (*Chironomus plumosus*), of which hosts may be seen dancing together any summer evening, is a well-known species, distinguished by the great beauty of the antennæ in the male.

The *Crane-Flies* are much larger insects, of which the Daddy-Long-Legs (*Tipula oleracea* and other species) is known to all. The peculiarly long legs are especially useful in enabling the animal to progress rapidly through grass. The eggs are laid in meadows, and the larvæ feed upon the roots of grasses.

All the preceding are distinguished by comparatively long antennæ, but in numerous families these appendages are very short. Well-known examples are the Horse-Stinger or Cleg (*Tabanus bovis*), a large speckled insect, the bite of whose female has been experienced by most of us in walking through woods; the notorious cattle pests called *Bot-Flies* (*Hypoderma bovis*, ox-bot; *Œstrus ovis*, sheep-bot; *Gastrophilus equi*, horse-bot); and the Tsetse-Fly (*Glossina morsitans*). Here, too, belong the Blue-Bottle (*Musca vomitoria*), House-Fly (*Musca domestica*), and their allies, constituting a family in which the piercing mouth-parts, as found in many of the preceding, have been reduced to mere vestiges, while a complex sucking proboscis is present, formed chiefly by the labium. The Fly's tongue is one of the commonest, most beautiful, and at the same time most complicated, of microscopic objects.

The *Fleas* are doubtfully associated with the Diptera as degraded forms living parasitically on the bodies of warm-blooded animals. The mouth-parts are modified for piercing and sucking, but present considerable differences from the arrangement described for the Gnats, &c. (p. 355). Wings are absent, and so are compound eyes, the organs of vision consisting only of a simple eye on each side. The long strong hind-legs are associated with great powers of leaping. The Common Flea (*Pulex irritans*) is not, as often imagined, the same species as those infesting cats, dogs, and other domestic animals. It appears, indeed, that there are very numerous sorts of Fleas associated with different Mammalia, even Bats being attended by their own peculiar species.

Order 4—Moths and Butterflies (Lepidoptera)

The insects of this order are, in the vast majority of cases, so characteristic-looking that they can be recognized at first sight mainly because they possess two large pairs of wings covered with minute variously-shaped scales (fig. 210), easily rubbed off as what is popularly called the "dust" of the wing. The presence of

these scales gives rises to all sorts and combinations of colours, often of extreme beauty. The male and female of the same species are often very different in appearance.

The *head*, which is well-marked off from the thorax, bears long antennæ and prominent compound eyes, while its mouth-parts are converted into a long *proboscis*, carried rolled up into a spiral when not in use (fig. 211). This organ is used to suck up the nectar of flowers or, in some cases, liquid matter of a less savoury kind, but differs entirely in structure from the corresponding organ of a Fly. The *upper lip* is inconspicuous, and the *mandibles* have disappeared altogether, while the *second maxillæ* are fused into a small plate bearing two conspicuous palps. The sucking part is formed entirely from the much-elongated *first maxillæ*, each of which is a long jointed structure grooved deeply on its inner side, so that when approximated to its fellow a tube is formed, the firmness of which is often enhanced by a series of interlocking hooks.

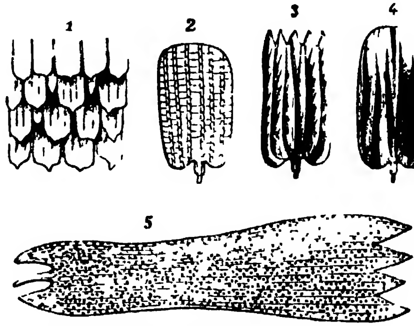


Fig. 210.—Scales from Wings of various Butterflies greatly enlarged.

The *thorax* bears not only the wings, but three pairs of weak legs, and is fairly well marked off from the *abdomen*, which is generally elongated, but may either be very slender or else broad according to the species.

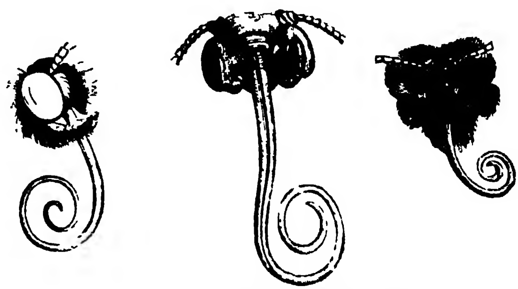


Fig. 211.—Heads and Proboscides of various Butterflies (enlarged)

The *life-history* of a Moth or Butterfly furnishes a good example of complete *metamorphosis*. The eggs are laid upon some special food-plant, and the larvæ which hatch out from them are ravenous *caterpillars* which feed upon vegetable matter or, more rarely, other substances. The head is provided with

an extremely short pair of antennæ, a group of simple eyes on each side, and biting mouth-parts. The cylindrical trunk is composed of eleven segments, the first three of which bear jointed legs corresponding to those of the adult; and besides this, from one to five of the other segments possess stumpy pro-legs which have sucker-like ends. Those at the posterior end of the body are often modified in various ways.

Caterpillars vary much in size, colour, and other characters, among which may be mentioned presence or absence of hairs, some being smooth and hairless, and others so hirsute as to have earned the popular name of "woolly bears" After leading a life entirely devoted to continuous feeding for a period varying from weeks to years, during which time the skin is frequently moulted as the body increases in size, the caterpillar becomes lethargic and passes into the quiescent pupa stage, constituting what is generally called a *chrysalis*. A continuous horny covering invests body and limbs alike, beneath which the parts of the perfect insect can be dimly traced. Innumerable methods of concealment and protection ward off to some extent the attacks of enemies during this helpless period. In some cases the chrysalis is to be found above ground suspended by a silken cord, or fastened to some object by a girdle of the same material, in which cases its colour commonly harmonizes with the surroundings and renders it inconspicuous. Other chrysalides are sheltered underground, and others again are to be found within cocoons, of which the silkworm is the most familiar illustration.

The last stage is reached when the perfect insect or *imago* issues from the chrysalis at a time dependent upon favourable conditions of temperature and various other factors, such, *e.g.*, as a suitable state of the particular food-plant upon which the eggs are laid.

The most convenient way of subdividing Lepidoptera is into the two groups of (1) Butterflies (Rhopalocera) and (2) Moths (Heterocera), of which the latter include a very much greater number of species, there being in Britain, for example, over 1900 sorts of Moths as against between sixty and seventy species of Butterflies.

1. *Butterflies* (Rhopalocera).—Butterflies for the most part are active in the daytime, especially during sunny weather. They can readily be distinguished from Moths by the antennæ,

which are club-shaped, and in most cases by their habit of shutting the wings together over the back when they alight. As the wings are far less brilliantly coloured on their under sides, which are then the only surfaces visible, a very efficient means of protection is afforded. The body is comparatively slender, and the demarcation between thorax and abdomen well-marked. The eggs are often sculptured in a way which renders them extremely beautiful microscopic objects, and the caterpillars may be naked, slightly hairy, or covered with branching spines. They posses five pairs of pro-legs. The angular chrysalis is sometimes simply suspended by the tail, or it may be fixed head upwards both by the tail and by a silken girdle round the thoracic region. It is frequently marked with metallic patches, to which the name chrysalis is due (Gk. *chrysos*, gold).

Butterflies are found in all parts of the world, and some common examples may here be mentioned.

The *Fritillary Family* is at once the largest and most widely distributed group of Butterflies. They are distinguished by the remarkable fact that their fore-legs are so much reduced as to be useless for walking purposes. Among British species are the Great Tortoiseshell (*Vanessa polychloros*) (fig. 212), the Small Tortoiseshell (*V. urticæ*), the Peacock Butterfly (*V. Io*), and the Red Admiral (*V. Atlanta*), in all of which the larvæ feed on nettles: the Painted Lady (*V. cardui*), an almost cosmopolitan species, of which the larvæ feed on thistles; and the Purple Emperor (*Apatura Iris*), a much rarer and finer insect, with a predilection for carrion. Closely related to these is the Resplendent Ptolemy (*Morpho Neoptolemus*), a gorgeous tropical Butterfly. *Morpho cypris* is brilliant blue, streaked with white.

Fig. 212.—Great Tortoiseshell Butterfly (*Vanessa polychloros*)

The family of *Whites* includes several British species which are perhaps more familiar than any other, partly on account of their conspicuous colour and partly owing to the ravages which their larvæ perpetrate in the kitchen-garden. The abdomen is enveloped by the basal part of the hind-wings. This family is

almost universally distributed, and British species are:—the Black-veined White (*Aporia cratægi*), the Large White or Cabbage Butterfly (*Pieris brassicæ*), the Small White or Garden White (*P. rapæ*), and the less common Green-veined White (*P. napi*); the beautiful little Orange Tip (*Anthocharis cardamines*), so named from the markings on the wings of the male; and the handsome Brimstone Butterfly (*Gonopteryx rhamni*), with angular outlines to the wings.

The *Swallow-tailed Butterflies*, which rival the Whites in their range of distribution, include numerous gorgeous tropical species, and the common name has reference to the slender "tail" into which the posterior margin of each hind-wing is often produced. The type genus, *Papilio*, comprises over 300 species, including our largest British form (*Papilo machaon*), now limited to the fen district. The huge Bird-winged Butterflies (*Ornithoptera*) of the Malay region belong to the same family, though they are without tails.

The family of *Blues* and *Coppers* is represented in all parts of the world, many of the tropical species being exceedingly beautiful. Two common British species of small size may be mentioned in illustration: the Common Blue (*Polyommatus alexis*) and the Small Copper (*Chrysophanus phlœas*).

2. *Moths* (Heterocera).—Moths are mostly nocturnal forms, differing from Butterflies in many particulars, among which may be mentioned the absence of knobs on the ends of the antennæ, and the habit of reposing with the wings spread out horizontally or folded round the body. The body is often much thickened, and the demarcation between thorax and abdomen is not well marked. In most cases there is a special "hook-and-eye" arrangement for uniting the wings during flight, and consisting of one or more bristles at the root of the hind-wings, which fit into a socket on the under side of the adjoining part of the fore-wings. The larvæ are either naked or more or less hairy, and may possess as many pro-legs as those of Butterflies, or fewer. The pupæ are rounded in outline, usually enclosed in a cocoon, and in many cases concealed underground.

The group may be divided into (I) Large Moths, including Hawk-Moths, Clear-Wings, Spinners, Owlets, and Loopers; and (II) Small Moths, embracing Leaf-Rollers, Leaf-Miners, Plume-Moths, and many others.

I. *Large Moths*, as the name indicates, are usually of considerable size, and agree with the Butterflies in the following characters:—The wings are elaborately veined, and the larvæ, which feed upon leaves, have downwardly-directed heads, and, usually, a curved line of horny bristles near the tip of each pro-leg. The abdomen of the pupa is devoid of transverse rows of spines.

Hawk-Moths are large swiftly-flying insects with a very long proboscis, suited for draining honey from flowers (such as honeysuckle) possessing a very long tubular spur. The caterpillars have smooth brightly-coloured skins, and are provided with five pairs of pro-legs, while a horn-like projection is found on the upper surface, near the hinder end of the body. The pupæ are found underground, enclosed in cocoons of earth. British examples are the Death's-Head Moth (*Acherontia Atropos*), with markings on the upper side of the thorax looking like a skull and cross-bones, and the Privet Moth (*Sphinx ligustri*). The larva of a common European species, the Pine Hawk-Moth (*Sphinx pinastri*) is very destructive to pine-trees.

The *Clear-Wings* are remarkable from the absence of scales on the wings, owing to which, and the nature of their markings, they resemble wasps, &c., this being no doubt a protective arrangement. The Hornet Clear-Wing (*Trochilium apiforme*) is a typical native species.

Spinners are large clumsy moths, clothed with abundant hair, and provided with a short proboscis. The colours are dull, and the two sexes differ considerably in appearance, *e.g.* in the character of the antennæ, which are plume-like in the male, and thread-like in the female. The caterpillars are more or less hairy, and before becoming pupæ spin cocoons, which may be entirely of silk, or contain a number of cast hairs in addition. One of the most beautiful British species belongs here, the Emperor Moth (*Saturnia carpini*), with an eye-like marking on each wing, and the caterpillar, abundant on heather, of emerald-green with pink tubercles. The spread of wing may be as much as 3 inches, but this appears small by comparison with exotic species, especially the Atlas Moth (*Attacus atlas*), in which the wings measure about a foot across. Among other native species may be mentioned the large Goat Moth (*Cossus ligniperda*), with wood-boring larva; the Tiger Moth (*Arctia caja*); the Puss Moth (*Cerura vinula*), with an extraordinary-looking caterpillar; the Buff-Tip (*Pygæra

bucephala); the Pale Tussock-Moth (*Dasychira pudibunda*); the Lackey (*Clisiocampa neustria*); and the Oak Eggar (*Lasiocampa quercus*). Spinner Moths, however, are best known from the Silkworm Moth (*Bombyx mori*), a native of China introduced into many countries for the sake of its silk.

Owlets form the largest group of the Lepidoptera, and include dull-coloured species, with comparatively small fore-wings, each of which is characteristically marked with a couple of spots, one round and the other somewhat kidney-shaped. The larvæ of many species, as "surface caterpillars", do much harm to crops, and the pupæ are found underground, enclosed in earthen cocoons. Common British species are: the Common Wainscot Moth (*Leucania pallens*), Yellow Underwing (*Triphæna pronuba*, fig 213), the Heart-and-Dart Moth (*Agrotis exclamationis*), and the Silver Y (*Plusia gamma*).

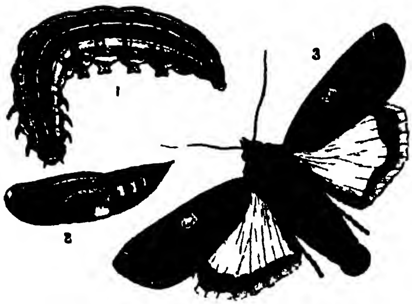


Fig 213.—Yellow Underwing (*Triphæna pronuba*) 1, Caterpillar 2, chrysalis, 3, adult

Loopers are moths of slender build, with broad thin wings and small antennæ. The caterpillar has but two pairs of pro-legs, placed right at the posterior end of the body, and this necessitates a curious mode of locomotion, which gives the name to the group. The body is stretched out to its full length, and then, while holding firmly by means of its three ordinary legs, the pro-legs are brought up and fixed close behind them, the body being thus thrown into a loop. Now, holding firmly by the pro-legs, the body is stretched forwards, and the ordinary legs attach themselves again. By repeating these manœuvres the caterpillar can move rapidly along in a curious looping fashion. When at rest the larva has a curious habit of attaching itself by the pro-legs, and stretching out the body at an angle to the surface of attachment, at the same time stiffening itself. This position can be retained for hours, and the caterpillar looks so like a short bare twig that it is rendered extremely inconspicuous to its enemies. Common British species are: the Brimstone Moth (*Rumia cratægata*), the Magpie or Currant Moth (*Abraxas grossulariata*), the Winter Moth (*Cheimatobia brumata*), and the Chimney Sweeper (*Tanagra chærophyllata*).

II. The *Small Moths*, as their name indicates, differ from the members of the other group in size, and usually possess long slender antennæ. The caterpillars, which burrow in vegetable substances or conceal themselves by rolling leaves together, have their heads forwardly directed, and a circlet of spines near the tip of each pro-leg, of which there are five pairs. The pupæ are generally distinguished by the presence of transverse rows of spines on the upper side of the abdomen. Among the groups may be mentioned Leaf-Rollers, Leaf-Miners, and Plume-Moths.

Leaf-Rollers are so named from the habit many of the larvæ have of feeding either between leaves which they have glued together with silk, or else inside individual leaves which have been rolled up and fixed in a similar way. Common British species are: the Green Oak Moth (*Tortrix viridana*), and the Codlin Moth (*Carpocapsa pomonella*), of which the caterpillar tunnels within the fruit of apples and pears.

The *Leaf-Miners* constitute a large group of small and very small moths with narrow hair-fringed wings. One of the prettiest species is the Little Ermine-Moth (*Hyponomeuta padella*), the larvæ of which keep together in companies as hatched out, and spin a considerable amount of web. They devastate the leaves of hawthorn, sloe, &c. Another beautiful but extremely small form is the Brown Dolly (*Lithocolletis corylella*), the caterpillars of which mine in hazel leaves. Unfortunately, however, the best-known are the different species of Clothes Moth (*Tinea pellionella, Trichophaga tapetzella*) (figs. 214 and 215).

Fig 214 — Adult stage of a Clothes Moth (enlarged)

Fig 215 — Larvæ of a Clothes Moth (enlarged)

The *Plume-Moths* are a comparatively small group of pretty little long-legged moths with wings split up into a varying number

of plume-like portions. Common British species are: the Common Plume-Moth (*Pterophorus pterodactylus*) and the Twenty-Plume Moth (*Alucita polydactyla*).

Order 5.—BEETLES (Coleoptera)

This is by far the largest order of insects, and includes forms which are for the most part easily recognizable, though the name of "beetle" is popularly but erroneously given to members of other groups, *e.g.* to the Cockroach. The wings of an average beetle are of very characteristic appearance and nature, as may be seen by examining such a typical example as the little Lady-Bird (*Coccinella*), which is at once known by its conspicuous colouring of black spots on a red ground (fig. 216). At first sight such an insect appears to have no wings at all, but every child who has induced a lady-bird to "fly away home", by persuasive shoves added to an alarming story of domestic calamity, knows better than that. The fore-wings are not, however, organs of flight, but horny wing-covers or *elytra* (see p. 345) stretching back over the abdomen and abutting against one another in the middle line. They protect the membranous hind-wings (fig. 217), which, when not in use, are hidden beneath them, and are not only folded longitudinally, as in a Cockroach, but also transversely, a very characteristic feature for beetles. The *head* is large, and bears a pair of compound eyes, and two antennæ varying greatly in shape according to the

Fig. 216.—Lady-Birds

1, Cluster of eggs; 2, egg, greatly magnified; 3, larva (magnified); 4, actual length of same; 5, 6, pupæ; 7, 8, varieties of Two-spotted Lady-Bird (*Coccinella bipunctata*); 9, Seven-spotted Lady-Bird (*C. septempunctata*).

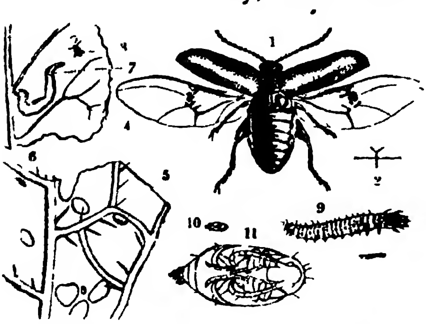


Fig. 217.—Stages of Turnip Flea Beetle (*Haltica nemorum*)

1, Adult (enlarged), showing wing-covers and wings spread out; 2, 3, natural size of same; 4, 5, eggs (enlarged); 6, 7, burrows of larvæ (enlarged); 8, 9, larva (natural size and enlarged); 10, 11, pupa (natural size and enlarged)

species. The *mouth-parts* are adapted for biting, and are built on the same plan as in the Cockroach (see p. 345), but with many differences in detail, as seen, for example, in the more complete fusion which has taken place between the two second maxillæ, and in the fact that these jaws are much reduced. The *life-history* of a beetle (figs. 216 and 217) exhibits a complete *metamorphosis*, the larva being a grub possessed, in most cases, of three pairs of legs corresponding with those of the adult, and becoming a pupa differing from that of a moth or butterfly as regards the limbs and wings, which form prominent projections instead of being merely indicated beneath the continuous horny covering.

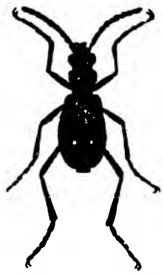


Fig. 218.—Green Tiger-Beetle (*Cicindela campestris*).

Only a few common species, representing important families, can be mentioned here.

Tiger-Beetles are very active, predaceous insects, including somewhere about a thousand species, and distributed generally throughout the world, though most abundant in the tropics. A common British form is the Green Tiger-Beetle (*Cicindela campestris*) (fig. 218), common on sandy banks, and distinguished by the beautiful golden-green colour of its upper surface. The larva is provided with enormous curved mandibles, and excavates a vertical burrow in which it lies in wait for prey.

Ground-Beetles are also predaceous, and even more widely distributed than the Tiger-Beetles, though much more numerous, there being some eleven thousand species. They are least abundant in the tropics. A large and well-known British species, the Violet Ground-Beetle (*Carabus violaceus*), so named on account of the dark violet sheen exhibited by its upper surface, is common in fields and gardens, and may also be found in houses, where it preys upon cockroaches and crickets.

Water-Beetles include ravenous forms which resemble ground-beetles in many respects, but are adapted to an aquatic life. The largest British form is the Great Water-Beetle (*Dytiscus marginalis*) (fig. 219), and here may also be included the Whirligig Beetle (*Gyrinus natator*), which almost everyone must have noticed twirling round and round at the surface of the water in ponds and ditches.

Rove-Beetles, possessing broad heads, narrow bodies, and short

elytra, agree with the preceding families in their carnivorous habits. Most familiar perhaps in Britain is the Devil's Coach-Horse (*Ocypus olens*), which has the curious habit of turning up its tail when molested (fig. 220).

Fig. 219.—Great Water-Beetle (*Dytiscus marginalis*)

Male to left, and female to right. Part of the fore-foot of male (enlarged) is represented in centre to show the pad and suckers with which it is provided.

The *Scarabs* rival the ground-beetles in number of species and include many large and handsome forms, distinguished by characteristic antennæ, of which the last few joints are so broadened out that when expanded they look like a small fan. The adults and larvæ feed either upon vegetable substances or on dung. Here belongs the largest British species, the Stag-Beetle (*Lucanus cervus*), in which the mandibles of the male resemble antlers. The largest-known beetles are not very distantly related, and forms commonly seen in museums are the Hercules-Beetle (*Dynastes hercules*) from tropical America, and the Goliath-Beetle (*Goliathus Drurei*), the male of the former species sometimes exceeding 5 inches in length, as against the 3 inches of our Stag-Beetle. One of the commonest British dung-beetles is the Dumble-Dor (*Geotrupes stercorarius*), a sluggish insect of bluish-black colour, often seen crawling slowly along country roads. An allied genus includes the Sacred Scarab (*Scarabæus sacer*) of the Egyptians.

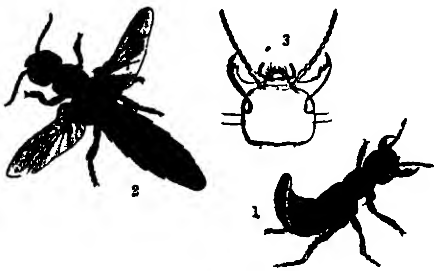


Fig. 220.—Devil's Coach Horse (*Ocypus olens*)

1, Standing with turned up tail; 2, flying; 3, head enlarged, to show eyes, antennæ and jaws.

The *Chafers* constitute a large and well-known group of the Scarab Beetles. Common British species are the Cockchafer (*Melolontha vulgaris*), the green-and-brown Garden Chafer (*Phyllopertha horticola*), and the beautiful golden-green Rose Chafer (*Cetonia aurata*) (fig. 221).

Weevils are small beetles with long snouts which do great damage to timber, fruit, and grain. Some ten thousand species are known. A common British form is the Nut Weevil (*Balaninus glandium*), which lays its eggs in hazel-nuts and acorns, upon the kernels of which the larvæ feed when they have hatched out. Two species of Weevil are represented in fig. 222.

Fig. 221.—Rose Chafer (*Cetonia aurata*)
1, Adult; 2, larva, 3, cocoon, 4, pupa.

Lady-Birds (fig. 216) are among the insects which are of great use to man, as they prey upon plant-lice, to which their larvæ are a veritable terror. Over a thousand species are known distributed throughout most regions of the globe. The commonest British species are the Seven-spotted Lady-Bird (*Coccinella septempunctata*) and the Two-spotted Lady-Bird (*C. bipunctata*), distinguishable by the number of black spots upon the red elytra.

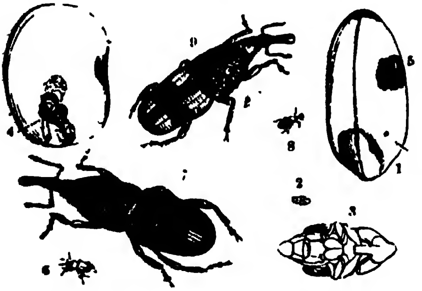


Fig. 222.—Corn-Weevil
1, Grain of wheat, showing the punctured hole; and 5, the exit of the perfect weevil. 2, Pupa (natural size), 3, magnified. 4, Grain of Indian corn, with weevil inside. 6, 7, Corn-Weevil (*Calandra granaria*), natural size and magnified. 8, 9, Rice-Weevil (*C. oryzæ*), natural size and magnified.

Order 6.—Membrane-winged Insects (Hymenoptera)

This very large order contains many thousand described species, including among many others the different kinds of bee, wasp, and ant. Not a few live in communities of exceedingly complex organization, and these display so much intelligence that there is much to be said for the view that the order is the highest among insects. Four membranous wings (fig. 223) are present, whence the technical name (Gk. *hymēn*, membrane; *pteron*, wing); they possess comparatively few nervures, and are not folded during repose. It will be remembered that in most Moths there is a "hook-and-eye" arrangement for coupling the wings together

during flight. In the present order the same end is brought about by a more perfect contrivance. On the front margin of the hind-wing, which is smaller than the fore-wing, a series of hooks will be found which catch on to a fold on the hinder margin of the latter, and due to a curling up of the edge. The complex *mouth-parts* are adapted for both biting and licking, as may be seen by careful examination of a hive-bee (fig. 223). The triangular *upper lip* will here be seen to overlap a pair of powerful *mandibles*, under which come the long *first maxillæ*, provided with cutting-blades and palps (in this species very small), and lastly follow the fused *second maxillæ*. These are drawn out into a slender tongue-like structure suited for licking, and grooved for the conduction of liquid.

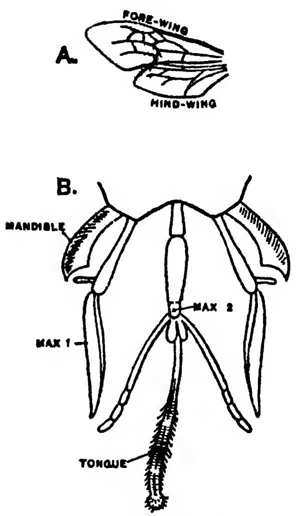


Fig 223.—Structure of Hymenoptera
A, Wings of a bee. B, Diagram of mouth-parts of Honey-Bee (*Apis mellifica*), much enlarged and widely separated.

Female Hymenoptera are either provided with a sting at the posterior end of the body, or else with a piercing arrangement (ovipositor) for making holes in which to lay the eggs. The *metamorphosis* is particularly well-marked. Larvæ resembling caterpillars, or it may be of worm-like appearance, hatch out from the eggs, which have previously been deposited in plants, the bodies of other insects, or sometimes in specially-constructed chambers (as in bees). The pupæ are generally enclosed in a cocoon of silk, and, as in beetles (see p. 366), their limbs project freely.

Three sub-orders are recognized:—1. Plant-Eaters, 2. Insect-Eaters, and 3. Stinging Hymenoptera.

1. *Plant-Eating Hymenoptera* include the *Saw-Flies* and *Wood-borers*, of which some thousand species have been described. The ovipositor of the female is adapted for boring holes in plants, and the abdomen does not in either sex narrow to a stalk at its base, as in a wasp or ant. The mouth-parts are not so specialized as in the example taken above. The larvæ resemble caterpillars, for which indeed they are often mistaken, but may easily be distinguished by the presence of more than five pairs of pro-legs in

addition to the three pairs of legs proper, while a caterpillar never has more than five pairs of pro-legs, and often fewer. Nor do these pro-legs possess, like those of most caterpillars, a curved row or circlet of minute bristles near their tips. Further, a "false" caterpillar has a rounded instead of a flattened head, moves its abdomen vertically up and down when disturbed, and curls it up in a state of rest.

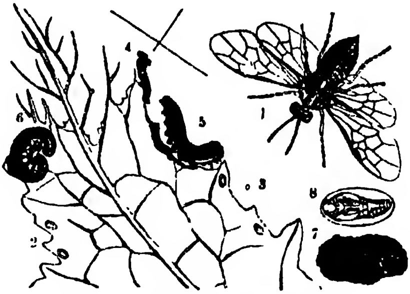


Fig. 224.—Turnip Saw-Fly (*Athalia spinarum*)
1, Adult female, enlarged (natural size represented to left of it); 3, 2, Eggs (natural size and enlarged); 4, 5, 6, larvæ; 7, cocoon; 8, pupa in cocoon.

The "saw" of a saw-fly consists of two curved saw-like blades protected by sheaths when not in use. The blades are worked alternately backwards and forwards, and the eggs slip down between them into the incision formed. A common species is the Turnip Saw Fly (*Athalia spinarum*) (fig. 224), the larvæ of which ravage the crop after which the insect is named.

Fig. 225.—Large Wood-Borer or Wood-Wasp (*Sirex gigas*)

In a *Wood-Borer* the blades corresponding to the saws of a saw-fly are fused together into a boring spine, which is used like an auger. A conspicuous species, not infrequently seen in this country, is the Large Wood-Borer (*Sirex gigas*) (fig. 225), also called Wood-Wasp from the transverse black and yellow bandings of its body. The female bores holes in pine-trees in which to lay her eggs, and from these, eyeless grubs hatch out which only possess the three pairs of ordinary legs. These larvæ burrow in the timber by means of their strong mandibles, and later on become pupæ enclosed in cocoons formed from silk mixed with fragments of wood.

2. The *Insect-Eating Hymenoptera* are so named because the larvæ are commonly parasitic within the larvæ of other insects,

though to this there are many exceptions. The abdomen is stalked, and the female is provided with a piercing ovipositor by which punctures are made for the reception of eggs. The larvæ are pale legless grubs. It is stated as probable that the sub-order contains 20,000 species or even more, which means an innumerable host of enemies to other insects. The Winter Moth (*Cheimatobia brumata*), for example, is attacked by no less than 63 different kinds of Hymenoptera belonging to this group. Two leading families are the Gall-Flies and Ichneumon-Flies.

Gall-Flies are so named because they puncture plants for egg-laying purposes, with the result that the wounded parts give rise to those peculiar excrescences known as "galls", of which the spherical brown bodies called "King Charles's oak-apples", common on the oak, are known to everyone who has been in the country. This tree indeed is peculiarly liable to the attacks of different species of gall-fly, which lead to the production of galls of totally different appearance, some resembling currants, others looking like little cones, and others again being in the form of circular scales ("oak spangles") on the backs of the leaves.

We may mention, as a specific example of a gall-fly, the form *Rhodites rosæ*, which is responsible for the tufted red galls often seen on wild rose-trees and known as rose-bedeguars or "old man's beard".

Ichneumon-Flies constitute a family of which nearly 6000 species have been described, over 1200 of these being British. The larvæ usually attack caterpillars, in or on which the eggs were laid by the parent. Insects of other kinds, and even spiders, are, however, attacked by some of the species. It was till recently thought that the parasite subsisted by devouring the non-vital parts of its host, but it is more probable that it simply absorbs the blood of the caterpillar through its skin.

One common ichneumon-fly (*Microgaster glomeratus*) lays its eggs in the caterpillar of the common white Cabbage Butterfly, within which they hatch out. When the unfortunate host has reached its full term of growth, and should be ready to turn into a chrysalis, it is too much enfeebled to do so. The unwelcome guests now bite their way out of the caterpillar and become pupæ on their own account, and it is no uncommon thing to find a dead caterpillar which has fallen a victim to ichneumon larvæ side by side with a little heap of pupæ belonging to these flies. Another

species (*Hemiteles melanarius*) (fig. 226) lays its eggs in the chrysalis of the Green-veined White.

3. *Stinging Hymenoptera* are generally distinguished by the presence of a sting in the female, which takes the place of the ovipositor found in the forms so far mentioned. Special cells are usually constructed in which the helpless larvæ are reared. As in the last sub-order, the abdomen is attached by a stalk, which may be extremely slender. Ants, Wasps, and Bees are here included, many of which live in social communities, the politics of which will be dealt with in another part of this book, and which in itself would require an entire volume to do it justice.

Fig 226.—The Green-veined White (*Pieris napi*), and an Ichneumon-Fly (*Hemiteles melanarius*), which lays its eggs in the chrysalis of the same. 1, 2, 3, 4. Adult female, eggs, caterpillar, and chrysalis of the butterfly. 5, adult female of the ichneumon-fly, of which natural size is shown by 6.

More than a thousand species of *Ants* have been described, of which over thirty are British. Among these are the large red Wood Ant (*Formica rufa*), the large "ant-hills" of which may be seen in fir-woods, the Slave Ant (*Formica fusca*), the Slave-making Ant (*Polyergus rufescens*), the Black Ant (*Lasius niger*), the Yellow Ant (*Lasius flavus*), and the Solitary Ant (*Mutilla Europæa*).

Sand-Wasps dig tunnels in the ground, at the end of which their eggs are laid. Many of them make a curious provision for their larvæ in the shape of insects, caterpillars, grubs, or it may be spiders, which they have stung in the nerve-cord so as to render them powerless without actually killing them. Among British forms may be mentioned the Path-Wasp (*Pompilius exaltatus*), which stores up spiders; the Common Sand-Wasp (*Ammophila sabulosa*), which buries caterpillars; and the Fly-storing Sand-Wasp (*Mellinus arvensis*), which does the same to flies.

Wasps are either solitary or social, the most familiar example of the latter kind being the Common Wasp (*Vespa vulgaris*), which, as is well known, constructs nests in banks and other places. The combs which these contain are constructed of a kind

of paper formed by working up bark and decayed wood to a sort of pulp. Another and larger social wasp is the Common Hornet (*Vespa crabro*), in which the front part of the body is of a reddish colour. Of solitary species the Mud-Wasps (*Odynerus parietum* and others) may be mentioned, which construct their cells of mud in the crevices of walls, the hollow stems of plants, and other places.

Fig 227 —Bees and Flowers of Broad-Bean

1, Wood Bee *B lucorum*) 2, 2, Holes cut by bee in bases of flowers 4, Humble-Bee *Bombus terrestris*) extracting nectar through one of the holes

Bees, like Wasps, include social and solitary species, the Hive-Bee (*Apis mellifica*) furnishing a good example of the former sort, that also includes the Humble-Bee (*Bombus terrestris*) (fig. 227), which makes its nests in the ground. In solitary bees the labium is much shorter than in the Hive-Bee. They belong to numerous genera, and include Leaf-Cutter Bees, which make their cells from pieces of leaf, Carpenter-Bees (*Xylocopa*), which cut out cells one above another in the trunks of trees, and Flower-Bees (*Anthophora*), forms which look something like humble-bees.

Order 7.—NET-WINGED INSECTS (Neuroptera) (fig 228)

This order, which is much smaller than some of those already dealt with, contains a great variety of forms which differ very widely in appearance. The most typical members of the order possess four membranous wings exhibiting an elaborate net-work of nervures, quite unlike the simple arrangement characteristic of Hymenoptera. The mouth-parts are usually adapted for biting. Eleven families are recognized, arranged in five groups; *i.e.*—1. Dragon-Flies, May-Flies, and Stone-Flies; 2. Flat-winged Neuroptera; 3. Caddis-Flies; 4. White Ants and Book-Lice; 5. Biting-Lice.

1. *Dragon-Flies, May-Flies*, and *Stone-Flies* all possess the four typical wings and pass through an aquatic larval stage. *Dragon-Flies* are among the most beautiful objects to be seen in the course of a summer walk in the country. The four large wings are of

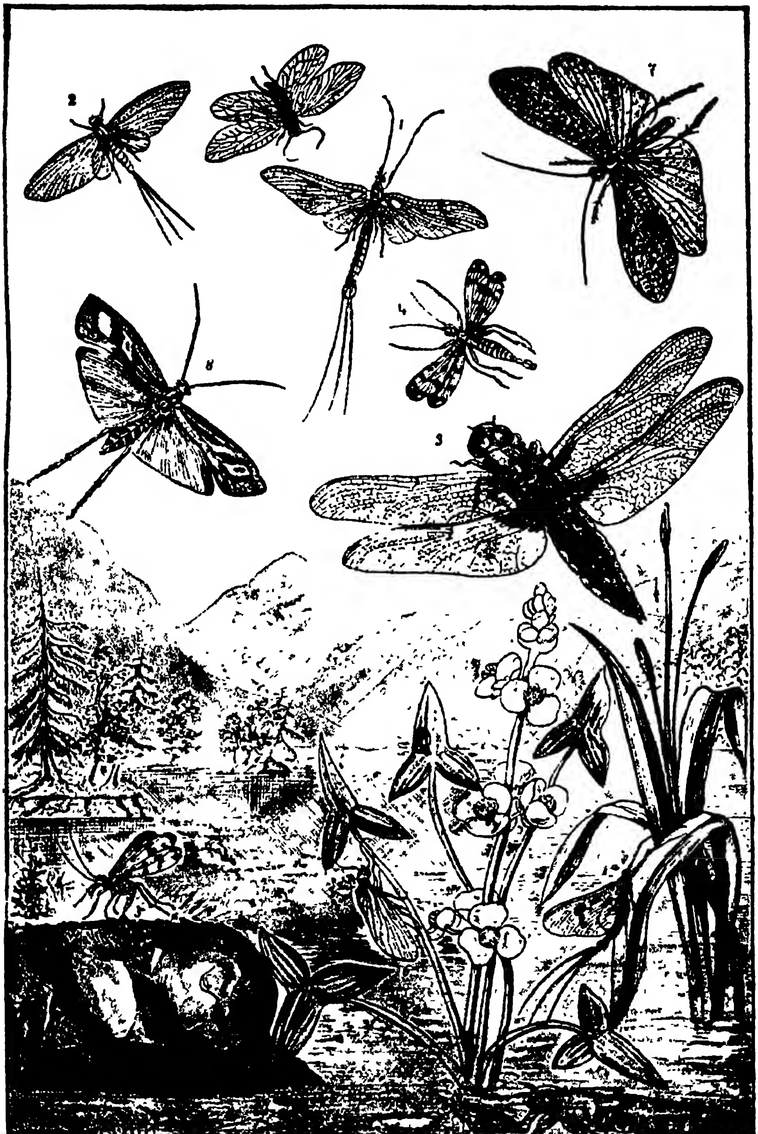


Fig. 228.—Net-winged Insects (*Neuroptera*)

1, 1*a*, 1*b*, Stages of common May-Fly (*Ephemera vulgata*); 2, another species of May-Fly (*Palingenia horaria*); 3, 3*a*, adult and larva of Horse-Stinger (*Libellula depressa*); 4, 5, Common Scorpion-Fly (*Panorpa communis*); 6, 6*a*, Alder-Fly (*Sialis lutaria*); 7, Large Caddis-Fly *Phryganea grandis*); 8, Diamond-spotted Caddis-Fly (*Limnophilus rhombicus*)

about equal size, and the long body is handsomely marked and coloured. The freely movable head is provided with very small antennæ, a pair of huge compound eyes, three simple eyes (ocelli), and biting mouth-parts. Dragon-Flies catch other insects on the wing, and their flight is exceedingly rapid, making them the swallows of the insect world. The eggs are laid either in water or attached to water-plants, and from them extremely voracious aquatic larvæ hatch out, which are distinguished by the possession of an extremely long transversely-jointed lower lip. This is usually known as the "mask", because when not in use it is folded up in front of the face, from which position it can be suddenly shot out for the capture of small animals. The action has been compared to that of an old-fashioned carriage-step. The larval condition is maintained for about a year or rather less, during which time a number of moults occur, while towards the end of the period the rudiments of wings make their appearance. There is no motionless pupa stage, but the full-grown larva climbs up the stem of some plant till it is above water, when its skin splits longitudinally along the dorsal surface, and the adult dragon-fly, which has been meanwhile forming within, gradually works its way out. Over forty species of British dragon-flies are known, of which the following may be mentioned:—The Great Dragon-Fly (*Æschna grandis*), a large reddish-brown insect, with lighter markings; the Horse-Stinger (*Libellula depressa*) (fig. 228), with broad abdomen, light brown, with yellow spots in the female and violet in the male; and the little Demoiselle Dragon-Fly (*Agrion puella*), with T-shaped head, and slender abdomen, black in the female and banded with light-blue in the male.

The *May-Flies* or *Day-Flies* are fragile insects in which the hind-wings are much smaller than the others, and the abdomen has two or three slender tails attached to it. The adult only lives a short time, though the traditional day may in some cases be extended to a fortnight. The life-history broadly resembles that of the dragon-flies, and the larva of some forms appears to live three years, an unusually long time, contrasting sharply with the brief existence of the imago. Something like 300 species have been described, and common British forms are the Common May-Fly or Gray Drake (*Ephemera vulgata*) (fig. 228) and the Green Drake (*E. Danica*). Some of the most successful lures of

the fly-fisher are copies of various may-flies, of which the two drakes are examples, as are also many of the "duns" and "spinners".

Stone-Flies are dull-coloured flattened insects with four membranous wings which, when at rest, are disposed so as to overlap the back and sides of the body. The antennæ are long, and there are usually two filaments of similar appearance attached to the tip of the abdomen. The life-history resembles that of the preceding two groups. Stone-Flies are widely distributed, and include a large number of species. The best-known British form is the Common Stone-Fly (*Perla bicaudata*), well known to anglers as a good bait for trout.

2. *Flat-winged Neuroptera* include Alder-Flies, Snake-Flies, Scorpion-Flies, Ant-lions, Lace-wing Flies, and other forms, in all of which there are four similar wings, not capable of being folded, but turned back when at rest so as to lie either flat, or sloping like the roof of a house. The adult possesses well-developed mandibles, contrasting in this respect with the last group of Neuroptera, in which the mouth-parts are much reduced. There is a terrestrial or aquatic larva, which becomes a quiescent pupa.

The Alder-Fly (*Sialis lutaria*) (fig. 228), which figures on the angler's list, is a brown insect with brownish wings, clumsy body, and long antennæ. The wings in repose cover the thorax and abdomen in a roof-like manner. It is common on river-banks in Britain. The cylindrical greyish eggs are deposited in patches on the stems of grasses or rushes near the water, into which the rapacious larvæ that hatch out from them find their way. Later on, they come out of the water and bury themselves in the soil, where they become pupæ.

Snake-Flies, of which there are several British species (*e.g. Raphidia ophiopsis*), are more slenderly built insects, sometimes found in woods. They are distinguished by the presence of a sort of neck, and there is an ovipositor in the female. The rapacious larva is found in rotten wood, where it passes into a pupa stage.

Scorpion-Flies are much more abundant in this country than Snake-Flies, and the Common Scorpion-Fly (*Panorpa communis*) (fig. 228) may be taken as a type. The name is due to the fact that the abdomen in the male ends in a pair of pincers, and its

hinder part can be curled up over the back like a scorpion's tail. The wings are narrow, and when at rest are held in a horizontal position. The head is of characteristic shape, for it is prolonged into a downwardly-directed beak, which has been compared in appearance to the face of a horse. Though the insect is small (about ½ inch long), its black body, yellow legs and beak, and wings speckled with white and brown make it a striking and beautiful object. The larva is predatory and terrestrial, being not unlike the false caterpillar of a saw-fly in appearance, possessing as it does three pairs of legs proper, followed by eight pairs of pro-legs. Later on, it passes into a quiescent pupa stage.

Ant-Lions are insects with slender body, four equal membranous wings, and antennæ clubbed like those of butterflies. They do not occur in this country, but are common on the Continent, where they have long attracted attention from the peculiar habits of the larvæ in the type-genus (*Myrmeleo*). It is these to which the name ant-lion was originally applied on account of the devastations they commit among those and other insects, their mode of operation being to dig pit-falls in the sand, at the bottom of which they remain buried, with only the enormous mandibles projecting.

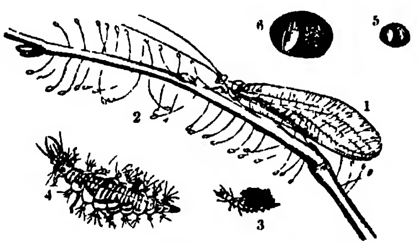


Fig 229.—Golden-eyed Fly (*Chrysopa vulgaris*)
1. Adult female, 2, stalked eggs 3, 4, larva natural size and enlarged, 5, 6, cocoon (natural size and enlarged).

Lacewing-Flies are represented by about fifteen native species, a common example being the Golden-eyed Fly (*Chrysopa vulgaris*) (fig. 229), an extremely fragile green insect with four gauzy wings, long slender antennæ, and brilliant eyes gleaming like gold. The eggs are attached to leaves by long stalks, and the voracious larvæ which hatch out from them are known as "aphis lions", a name fully justified by the effective manner in which they keep plant-lice in check.

3. *Caddis-Flies* (fig. 228) in the adult condition look rather like moths, but their wings are hairy instead of scaly, and their larvæ are aquatic "caddis-worms", remarkable for the habit of forming protective cases from sand-grains, bits of stick, or other foreign matters. A caddis-worm is something like a caterpillar,

devoid, however, of pro-legs, while at the end of its tail is a pair of pincers by which it can attach itself firmly to the case. The food is mainly of vegetable nature. After from seven to ten months the larva closes the opening of the tube with silk and passes into the pupa stage, which, after remaining quiescent for two or three weeks, bites its way out of the case and swims on its back to some plant or other object up which it can climb out of the water. The pupal skin then splits, and the caddis-fly emerges.

4. *White Ants*, more correctly called *Termites*, since they have nothing whatever to do with ants proper, are but too well known to the inhabitants of tropical countries on account of the havoc they work with wooden furniture and the like. They are social insects, living in communities organized in an extraordinarily complex manner, about which particulars will be given in the sequel. In every community both winged and wingless individuals may be found, the former possessing four very long narrow wings of the kind characteristic of the order, which are held flat on the back when at rest. There is but a slight metamorphosis. Two species are found in South Europe (*Calotermes flavicollis* and *Termes lucifugus*), but the most remarkable forms are natives of tropical Africa, and some of these (*e.g. Termes bellicosus*) construct nests of earth which may be as much as 14 feet high.

Book-Lice are minute forms of somewhat doubtful affinities, and most familiarly known by the wingless species giving the name to the group, but also including the "death watches" (*Atropos divinatoria* and others), commonly reputed by the superstitious to herald death by a ticking noise, though the sound is more probably produced by a wood-eating beetle (*Anobium*). The winged species, which are the most numerous, are to be found feeding on lichens, fungi, and other plants. Of the four membranous wings, which are provided with but few nervures, the hind ones are much the smaller. The antennæ are very long. There is but a slight metamorphosis. Among the British winged species may be mentioned *Psocus fasciatus*.

5. *Biting-Lice* are small wingless, large-headed creatures which live on the skins of birds and mammals, and must carefully be distinguished from ordinary lice (p. 354), in which the mouth-parts are adapted for piercing and sucking. The common

fowl is infested by no less than five species (*Menopon pallidum* and others), and the "dust baths" in which this bird indulges are no doubt taken with a view of getting rid of these and other parasites. Mammals are less troubled with attacks of the kind, the dog being an example of animals which are thus attended. *Trichodectes latus* is the name of its unwelcome guest.

Order 8.—Straight-winged Insects (Orthoptera)

The Cockroach, of which an account has already been given, may be taken as a type of this order, which also includes such familiar forms as locusts, grasshoppers, earwigs, and crickets. The *mouth-parts* are adapted for biting, and it is particularly to be noticed that the second maxillæ are not so closely fused together to form a lower lip or labium as in most other insects. The *fore-wings* are modified into leathery wing-covers, and the large membranous hind ones are usually traversed by nervures radiating from the point of attachment, and are thus enabled to fold up in a fan-like manner when not in use. There can scarcely be said to be a metamorphosis, for the young insects when just hatched differ from the adult mainly in size and in the absence of wings, while there is no quiescent pupa stage. It is supposed that at least 10,000 species of recent Orthoptera exist, including the largest known insects, but of this large number less than forty are native to Britain. A distinction is drawn between: 1. Running Orthoptera, including Earwigs, Cockroaches, Soothsayers, Stick-Insects, and Leaf-Insects; 2. Leaping Orthoptera, embracing Grasshoppers, Locusts, and Crickets.

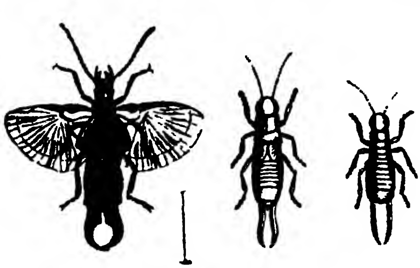


Fig. 230.—Common Earwig (*Forficula auricularia*) Adult (line indicates actual size) and earlier stages

1. In *Running Orthoptera* all three pairs of legs are pretty much alike. The Common Earwig (*Forficula auricularia*) (fig. 230) may be taken as a type of a family in which the wings are folded up in a remarkably complex manner under the short wing-covers, and the tail is provided with curved forceps. No satisfactory explanation has been given of the curious

popular notion that these insects are in the habit of entering the human ear, for this does not appear to be the case, and though it is true that the hind-wings are strikingly ear-shaped, they are so rarely seen unfolded that it may be doubted whether this has to do with the name "earwig".

Cockroaches are widely distributed insects, especially common in tropical regions. Only three small species appear to be indigenous to Britain, for the familiar "black beetle" is undoubtedly an importation. Some of the exotic species are brightly coloured, while others are wingless.

Soothsayers or *Praying-Insects* form a remarkable group dependent upon a warm climate, and often assuming the most extraordinary forms, calculated in many cases to harmonize with the surroundings, being thus rendered inconspicuous to their prey, which consists of other insects. The front-legs are modified into seizing-organs, and it is the curious way in which these are extended that has given rise to the common names, as, *e.g.*, that of Praying Mantis (*Mantis religiosa*) applied to a French species, the only European one found at any great distance from the Mediterranean shores. A Mantis in such an attitude is, however, merely on the look-out for insects, and not in a prophetic or devout frame of mind.

Stick- and *Leaf-Insects* assume even more remarkable forms than the members of the preceding family, and mostly have a close resemblance to sticks, leaves, pieces of bark, and other parts of plants, which in this case may be looked upon as a protective arrangement, for, unlike the Soothsayers, they affect a vegetable diet. They are widely distributed through the warmer parts of the globe, and some of them may be as much as 9 inches long.

2. *Leaping Orthoptera*, in accordance with their habit of springing, possess very large hind-legs. Remarkable structures related to hearing are usually present, and the males generally possess musical organs as well. Three families are recognized—Locusts and Grasshoppers, Green Grasshoppers, and Crickets.

Locusts and *Grasshoppers* are distinguished by the shortness of their antennæ and the presence of auditory organs in the first segment of the abdomen. The familiar little grasshoppers of British fields represent a number of species of varying size, some of the larger belonging to the genera *Stenobothrus* and *Gomphocerus*.

while the very smallest are included in the genus *Tettix.* The characteristic chirping is produced by rubbing the inner side of the hind-legs against the outer surface of the front wings, the former being provided with a ridge made up of small peg-like projections. The sounds audible to human ears are produced only by the male.

What are popularly known as "locusts" are simply species of grasshopper, which from time to time appear in swarms

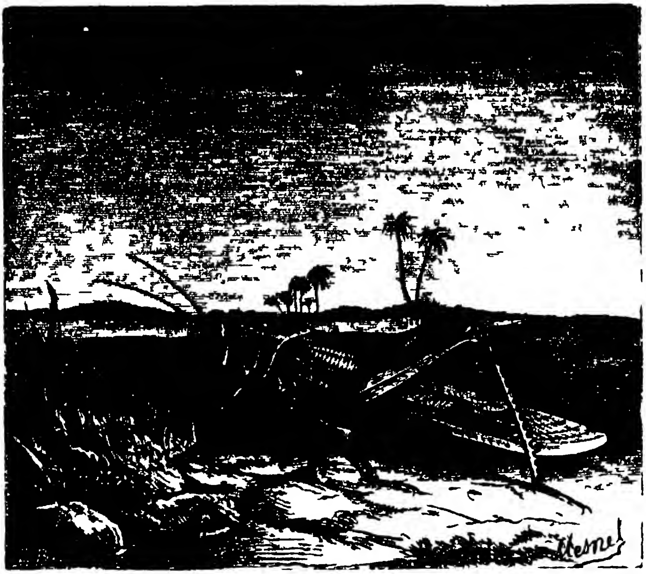


Fig. 231.—Migratory Grasshopper—"Locust" (*Acridium peregrinum*)

which migrate from place to place and do a vast amount of damage. The best-known species is the European migratory locust, which ranges from China to the Atlantic. A large species (*Acridium peregrinum*) (fig. 231), common in North Africa, is probably the locust mentioned in the book of Exodus.

Green Grasshoppers are easily distinguished from the members of the preceding group by their extremely long and slender antennæ. There are generally auditory organs situated in the front legs just below the knee. Chirping organs, when present, are placed on the bases of the fore-wings, the left carrying a roughened edge (file) and the latter a sharp edge. In most species the female possesses a long egg-laying tube or ovipositor.

The most conspicuous British species is the Large Green Grasshopper (*Locusta viridissima*) which, despite its generic name, is not a locust at all. Other examples are the North American Katydids.

Crickets agree in many essential particulars with the members of the preceding group, possessing as they do long, slender antennæ and similarly situated musical and vocal organs, while the female is usually provided with an ovipositor. There are, however, differences in detail; *e.g.* the tarsus is usually three-jointed instead of four-jointed, and the musical organs involve a larger part of the wing. There are four different kinds of cricket in the British area, of which by far the most familiar is the House-Cricket (*Gryllus domesticus*), which is one of the animals most constantly associated with human dwellings, and is not unconnected with superstitious ideas. Habit has rendered its chirpings agreeable to our ears, and Dickens's ever-popular story, *The Cricket on the Hearth*, gives it an interest which few Orthoptera can boast. It is perhaps rather unromantic to add that in dramatic presentments of the tale the all-important chirp is imitated by using a glass-stoppered bottle, the stopper of which is twisted round so as to produce a creaking sound. This particular insect ranges over a large part of the Old World, and also occurs in North America. Its distribution has probably been extended by human agency. Of the two British species of Field-Cricket, one (*Nemobius sylvestris*) is small in size, while the other (*Gryllus campestris*) is a good deal larger than the Common Cricket, and usually black in colour. The Mole-Cricket (*Gryllotalpa vulgaris*) (fig. 232) is a remarkable form, practically limited to the south of England with us, though common on the Continent. It burrows underground by means of its remarkably modified fore-feet, and its habits will be dealt with elsewhere.

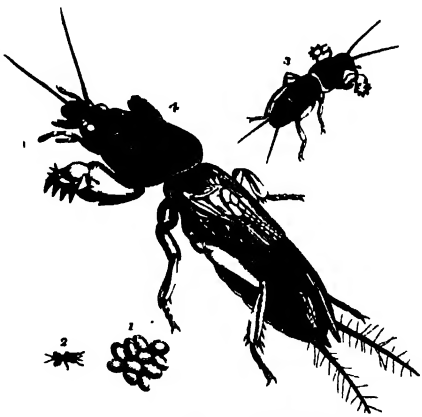


Fig. 232.—Mole-Cricket (*Gryllotalpa vulgaris*)
1, Eggs; 2, 3, larvæ; 4, adult.

Order 9.—Wingless Insects (Aptera)

This is a group of small inconspicuous insects which are of great interest theoretically, as they are probably to be regarded as insects in their simplest form, *i.e.* are of "primitive" nature. They never possess any traces of wings, nor do they appear to be descendants of winged ancestors, as is the case with the numerous wingless insects placed in other groups. The segmentation of the body is more clearly marked than in other insect orders, and the segments are not so specialized, besides which small abdominal appendages are not uncommon. The horny covering of the body is comparatively delicate. Two sub-orders are recognized:—1. Tassel-Tails (*Thysanura*) and 2. Springers (*Collembola*).

1. *Thysanura.*—The most marked feature of the sub-order consists in the presence of two or three long styles projecting from the hind end of the body. Probably the commonest British species is the Silver-Fish (*Lepisma saccharina*) (fig. 233), found in brown sugar and old books. It possesses three tail-filaments, and its silvery lustre is due to the presence of peculiar scales, which make beautiful microscopic objects. Another species, common in the crevices of rocks at the sea-side, is *Machilis maritima*, which is not unlike the preceding, but grey in colour instead of silvery.

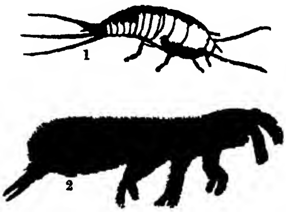


Fig. 233.—Aptera (magnified). 1, Silver-Fish (*Lepisma saccharina*); 2, Glacier-"Flea" (*Desoria glacialis*)

2. *Collembola.*—Many, but by no means all, of these possess a curious springing apparatus in the form of two stiff bristles which can be folded under the body and secured by a sort of catch projecting from the third segment. When released the animal is thrown into the air much like the "jack-jumper" children are so fond of fabricating from the "merrythought" of a goose. They are common under bark, dead leaves, stones, &c., and one species (*Podura aquatica*) may often be seen floating on the surface of stagnant pools. Some kinds are abundant in Alpine regions, on the surface of snow or ice, and among these may be mentioned the Glacier-"Flea" (*Desoria glacialis*) (fig. 233). The Collembola are not all provided with a springing

apparatus, and of these special interest attaches to *Anurida maritima*, remarkable for its habit of floating on the surface of rock-pools along certain parts of the coast. As remarked elsewhere, insects as a rule are very intolerant of salt water.

Class 2.—SPIDER-LIKE ANIMALS (Arachnida)

This class is constituted by Scorpions, Spiders, Mites, and other allied forms, though the affinities of some of these is more than doubtful. The majority of species live upon animal matter, and many of them pursue living prey. Arachnids are popularly confused with insects, from which, however, they differ in many

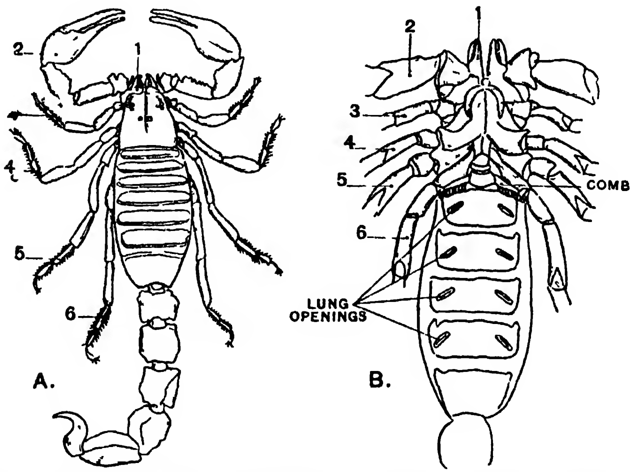


Fig. 234.—Scorpion, seen from above (A) and below (B). 1, Chelicerae, 2, pedipalps, 3-6, walking legs.

important particulars. These differences, as well as the points of agreement, will be best understood by briefly describing a Scorpion as a type (fig. 234). Spiders are more familiar to us in this country, but as they are much specialized it will be better to take them later. In dealing with the Scorpion, comparison may well be made with the account of a typical insect given on pp. 343–350.

The obviously segmented body is protected by a firm horny coating, which is very thick and hard in some places, while in others it is comparatively soft and flexible, so as to permit of a certain amount of movement. The body is not divided, as in

an insect, into well-defined head, thorax, and abdomen, for the parts commonly considered as equivalent to the first two of these are fused together into one mass known as the *cephalo-thorax*, which consists of at least six segments, for it bears six pairs of appendages. The remainder of the body is made up of twelve rings or segments, the last five forming a narrow *tail* which is carried bent up over the body, and bears at its tip a pear-shaped spine on the sharp end of which open two poison-glands. Here we have an example of a true "sting", like that of a bee or wasp, as contrasted with the biting arrangements found in serpents, bugs, and gnats.

The *appendages* of a Scorpion differ strikingly from those of an insect. Instead of antennæ, three pairs of jaws, and three pairs of walking-legs, we find two pairs of grasping organs and four pairs of walking-legs, while feelers or antennæ are not present as such. The first pair of these appendages are short, strong, forwardly-directed *nippers* (cheliceræ), and they are followed by a very large second pair (pedipalps), which end in strong *pincers* much like those of a lobster and used for seizing prey. The bases of these appendages are adapted for biting. The possession of eight *walking-legs* is as characteristic of an Arachnid as that of six is of an insect, and this affords the simplest means of distinguishing the members of the two classes.

The two segments which immediately succeed the cephalo-thorax also bear structures which are interpreted as appendages, the first being fused into a small plate (operculum) notched behind, while the others are comb-shaped organs (pectines), which probably have a tactile function.

An ordinary insect breathes by means of air-tubes which open to the exterior by a series of pores on each side of the body, but the respiratory organs of a Scorpion consist of four pairs of "lung-books" which open by a corresponding number of oblique slits placed on the under side of the segments following the one upon which the comb-shaped organs are borne. Each of these breathing organs consists of a cavity into which a large number of thin plates project, these being packed together in a way which suggests the leaves of a book, hence the name lung-"book". An insect, again, typically possesses a pair of large compound eyes, and simple eyes may be present in addition. Here the eyes are all simple and are arranged on the upper side

of the cephalo-thorax, two of them being close together near the middle line, while the remainder form a couple of groups, one on each side, near the front end of the body. Each of these groups contains from two to five separate eyes. The development takes place without metamorphosis.

The class is divided into the following orders:—

1. Scorpions (SCORPIONIDÆ).
2. False Spiders (SOLPUGIDÆ).
3. False Scorpions (PSEUDOSCORPIONIDÆ).
4. Whip-Scorpions (PEDIPALPI).
5. Harvestmen (PHALANGIDÆ).
6. Spiders (ARANEIDÆ).
7. Mites (ACARINA).

To these are usually added two small groups of doubtful affinities, *i.e.*—

8. Tongue-Worms (LINGUATULIDÆ).
9. Bear-Animalcules (TARDIGRADA).

Order 1.—SCORPIONS (Scorpionidæ)

Scorpions, all of which conform to the description already given, are widely distributed throughout the warmer parts of the globe. Two common South European species are the little House-Scorpion (*Euscorpius Europæus*), which ranges as far as the Tyrol and Carpathians; and the much larger Field-Scorpion (*Buthus Europæus*), common in the Mediterranean countries. The largest and most poisonous forms are the black *Rock-Scorpions* of Africa and India, which may be as much as 9 inches in length. These belong to the type-genus *Scorpio.*

Order 2.—FALSE SPIDERS (Solpugidæ)

The order of False Spiders includes a small number of species having a wide distribution, and mostly limited to warm countries. A well-known type is the Common False-Spider (*Galeodes araneoides*) (fig. 235), found in South Russia, Persia, Arabia, and Egypt, and much feared on account of its poisonous bite. The Kalmucks, Kirghiz, and other nomad tribes avoid regions where it abounds, for its attacks are not limited to human

beings, but extend also to domestic animals, such as sheep, and camels. This creature resembles a large spider in appearance: its body is about 2 inches long and its legs long and hairy. There are great differences of structure and proportion as compared with a Scorpion. The body is unique among Arachnids in being distinctly divided into *head*, *thorax*, and *abdomen*, much as in an insect, and the last region is composed of ten segments and cylindrical in shape, there being no sting-provided tail. A further resemblance to insects is found in the breathing organs, which consist of *air-tubes*, opening to the exterior by three pairs of stigmata situated on the under surface, the first at the bases of the second legs, and the others on the abdomen. As in a Scorpion, the first appendages are *nippers*, here of very large size, and constituting the chief offensive weapons, since poison glands open upon them. The *pedipalps*, however, are not, as in a Scorpion, stout and pincer-bearing, but slender leg-shaped structures having a forward direction and acting as tactile organs. The first pair of legs closely resemble the pedipalps in appearance and function, and it may be noted that these four similar appendages are provided at their bases with cutting projections, situated at the sides of the mouth and serving as jaws. The remaining legs are attached to the thorax, as in an insect, the resemblance being emphasized by the fact that each ends in a claw-bearing tarsus. There is nothing to correspond to either the operculum or the combs of a Scorpion, and only two *simple eyes* are present, placed on the front of the head close to the middle line.

Fig 235.—Common False Spider *Galeodes araneoides*

Order 3.—False Scorpions (Pseudoscorpionidæ)

False Scorpions are minute widely-distributed animals not unlike Scorpions in appearance, the resemblance being due to similarity in the appearance and structure of the cheliceræ, pedipalps, and walking-legs. There are, however, no poison-glands, and the broad flat abdomen does not narrow into a tail. Breathing is effected by means of *air-tubes*, which open on the under side

of the abdomen by two pairs of stigmata. *Spinning glands* open on the chelicerae, and the *simple eyes*, two or four in number, are situated on either side of the front of the head.

A common European species is the little Book-Scorpion (*Chelifer cancroides*) (fig. 236), often found in old books and similar dark places.

Fig. 236 – Book Scorpion (*Chelifer cancroides*), enlarged. Natural size indicated by line.

Order 4.—Whip-Scorpions (Pedipalpi)

The Whip-Scorpions make up a small but widely-distributed order, the members of which are fairly large in size. They are found in the warmer parts of both hemispheres, and considerable interest attaches to them, owing to the fact that they are in some respects intermediate between Scorpions and Spiders, on which account they are sometimes called Scorpion-Spiders. A typical Whip-Scorpion (*Thelyphonus*) looks not unlike a real Scorpion, the pedipalps being large and provided with pincers, and the abdomen narrowed into a sort of tail, reduced, however, to a mere filament. The breathing organs are lung-books (two pairs), and the eyes are arranged in a central and two lateral groups. Among the important differences from Scorpions may be noted—chelicerae provided with claws, not nippers, modification of the first pair of legs into tactile organs, and distinct marking off of the abdomen.

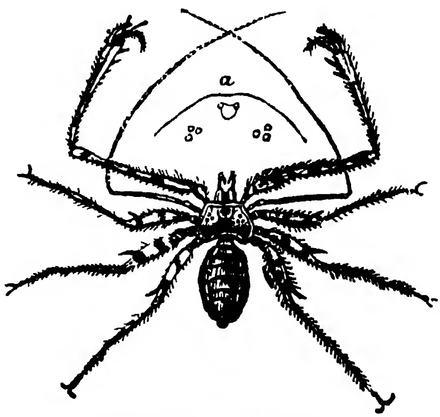


Fig. 237.—A Whip-Scorpion (*Phrynus*) *a*, Front of cephalo-thorax, enlarged to show eyes.

Some of the other genera (as *Phrynus*) (fig. 237) approximate more closely to the Spiders, for the pedipalps possess claws instead of pincers, and the abdomen is joined to the rest of the body by a narrow waist. The tail filament is only represented by a button-like knob.

Order 5.—Harvestmen (Phalangidæ)

Harvestmen constitute a large and almost universally-distributed order, represented in this country by some two dozen species. They are common in our fields and are generally mistaken for spiders, from which, however, the native species can at once be distinguished by the great length and slenderness of the four pairs of legs, and the fact that the small oval body is not marked off distinctly into regions. The chelicerae are provided with relatively large pincers, but the pedipalps are usually short and leg-like. The breathing organs are air-tubes which open by a pair of stigmata on a forward prolongation of the abdomen, just behind the bases of the first legs. A pair of simple eyes is borne on the upper surface of the cephalo-thorax. *Phalangium opilio* is one of the commonest native species (fig. 238).

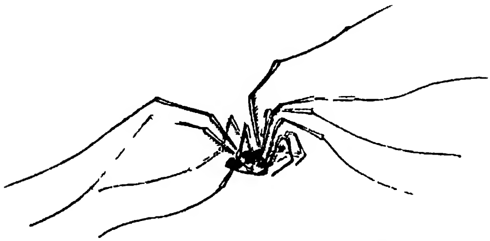


Fig 238.—A Harvestman (*Phalangium opilio*)

Order 6.—Spiders (Araneidæ)

Spiders make up a very large and widely-distributed order, of which there are several thousand known species. A well-known British form is the large Garden-Spider (*Epeira diadema*) (fig. 239), which constructs large regular webs resembling a wheel in shape. The ground-colour varies from yellowish to dark brown, diversified by darker markings, and usually presenting a conspicuous white mark on the upper side of the abdomen, whence the German name of "cross-spider" (*Kreuzspinner*), and the French name "cross-carrier" (*porte croix*). As in a scorpion, the head and thorax are closely fused together, but the large egg-shaped abdomen is connected by a narrow wasp-waist to the rest of the body, and the segments of which it is made up are so intimately united together that the boundaries between them cannot be made out.

The first pair of appendages (*chelicerae*) are two-jointed, and

of very characteristic construction, for the sharp curved end-joint, at the tip of which a pair of poison-glands open, can be folded down on the basal joint, much as the blade of a pocket-knife folds down on the handle. In this way an efficient grasping and holding organ is formed. The *pedipalps* are slender forwardly-directed structures, looking something like antennæ. As in

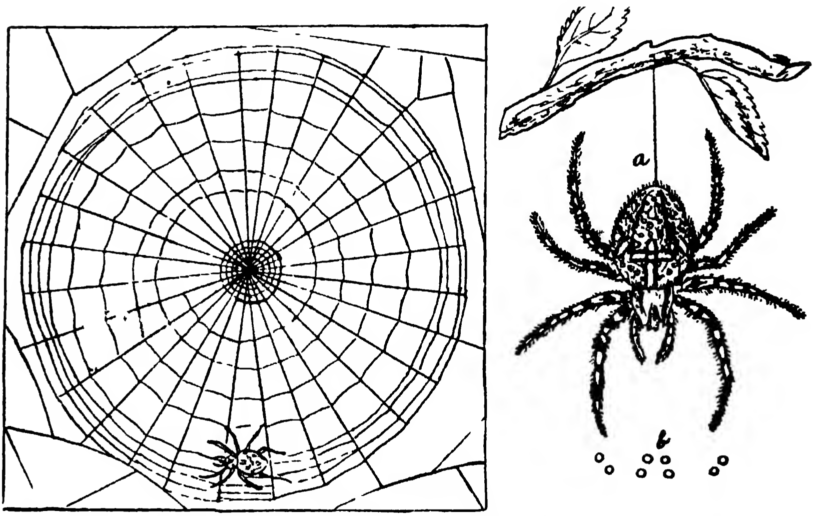


Fig 239 —Garden-Spider (*Epeira diadema*) and Web *a*, Female spider; *b*, arrangement of eyes.

Scorpion their basal joints are provided with cutting edges, which work against one another and act as jaws. The tips of the pedipalps are curiously modified in the male. The four pairs of *legs* are strong and of considerable length. Each of them is provided at its tip with several toothed claws, serving as efficient grasping organs.

As regards *breathing organs*, the Garden-Spider combines the arrangements characteristic of Scorpions on the one hand and Insects on the other. There are two lung-books, which open by a pair of slits on the under-side of the abdomen, near its base, while farther back there is a single aperture, situated in the middle, and opening into a set of air-tubes.

One of the most striking peculiarities of an ordinary spider is its power of spinning webs; indeed the word spider probably means "spinner". The silk is made by a large number of spinning-glands situated in the hinder part of the body, and

opening upon conical "spinnerets", of which there are six in the Garden-Spider, four large and two small. They will be found as conical projections on the under side of the abdomen near its tip.

The Garden-Spider possesses eight *simple eyes*, situated on the upper side of the cephalo-thorax, at its front end. Four of them are comparatively large and are placed at the corners of a square, on each side of which are a pair of rather smaller ones. As in Arachnids generally the young resemble the adult when hatched, except in size.

There are two sub-orders: 1. Segmented Spiders, and 2. Unsegmented Spiders.

1. *Segmented Spiders* are represented by certain large East Indian species, characterized by well-marked segmentation of the abdomen and the possession of two pairs of lung-books, agreeing in these respects with the whip-scorpions. A further peculiarity is the presence of eight spinnerets, grouped together on the under-side of the abdomen, and placed much farther forwards than in an ordinary spider.

2. *Unsegmented Spiders* include all the common forms, of which Epeira has been taken as a type. The sub-order is again divided into two groups according to the number of lung-books present, *i.e.* into Four-lunged Spiders and Two-lunged Spiders.

Four-lunged Spiders include the largest members of the order, which excavate burrows in the ground and line them with silk, but do not construct snaring-webs. Some of these prey upon small birds, *e.g.* the Bird-eating Spider (*Mygale avicularia*), a gigantic South American form often seen in collections. Here also are included the *Trap-door Spiders* (*Cteniza* and *Nemesia*) of South Europe and elsewhere, which make hinged lids to their burrows. There is only one British species (*Atypus Sulzeri*), which burrows in damp earth.

Two-lunged Spiders, of which *Epeira diadema* is a typical example, embrace the large majority of species, and all the British forms except Atypus. Only some of the kinds construct snaring-webs, and among these may be mentioned, in addition to the Garden-Spider, the common House-Spiders (*Tegenaria domestica* and *T. civilis*), and the Hedge-Spider (*Agalena labyrinthica*), which constructs strong horizontal webs on bushes, hedges, &c. A very interesting aquatic form is the Water-Spider (*Argyroneta*

aquatica), which constructs a thimble-shaped nest under water, attaching it to surrounding objects by mooring-strands which also serve to snare prey. The nest is filled with air, which the spider brings down in the form of bubbles adhering to its hairy abdomen.

Examples of common British spiders which do not construct webs are the Wolf-Spiders (*Lycosidæ*), and the handsomely-striped Harlequin-Spider (*Salticus scenicus*), distinguished by its leaping powers.

Order 7.—MITES (Acarina)

Mites, as their name indicates, are minute forms, and they embrace an exceedingly large number of species, some of which are found almost everywhere. A typical example is the Cheese-Mite (*Tyroglyphus siro*) (fig. 240). The abdomen is unsegmented and closely fused with the cephalo-thorax, the entire body being oval in shape. The small cheliceræ are provided with pincers, and the pedipalps are short and slender. The usual four pairs of walking-legs are present, two directed forwards and two backwards. Respiratory organs are absent. Another well-known species is the "Red-Spider" or "Money-Spinner", which lives on the juices of leaves and spins a protective web. One of the chief features in which it differs from the Cheese-Mite is in the possession of breathing organs, which are in the form of air-tubes. Other examples of the group are Ticks, Mange-Mites, and similar pests, which will be dealt with in another section.

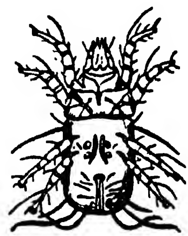


Fig 240.—Cheese-Mite (*Tyroglyphus siro*), seen from below Enlarged forty times

Fig 241.—Tongue-Worm (*Pentastomum tænioides*)

Order 8.—TONGUE-WORMS (Linguatulidæ)

Tongue-Worms are worm-like forms which in the adult condition are found as parasites in the nasal cavities of Dog and Wolf. The only appendages are two pairs of hook-like structures in the neighbourhood of the mouth. *Pentastomum tænioides* is the type (fig. 241).

Order 9.—BEAR-ANIMALCULES (Tardigrada)

Bear-Animalcules are minute creatures found in damp moss, or sometimes in salt or fresh water. The shape of the body ludicrously suggests an unlicked bear-cub (fig. 242). There are four pairs of stump-like legs, each provided with a pair of claws at its tip. The only representatives of jaws are to be found in a pair of sharp stylets which can be protruded from the mouth.

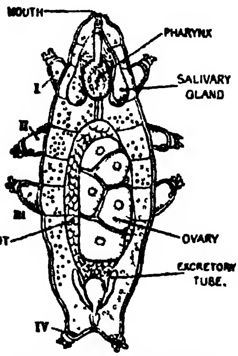


Fig 242.—A Bear-Animalcule (*Macrobiotus*), much enlarged and seen from above. I–IV, walking legs

CLASS 3.—CENTIPEDES AND MILLIPEDES (MYRIAPODA)

Centipedes and Millipedes, which make up the third class of Jointed-limbed Invertebrates, are of simpler structure than the average members of the preceding classes, Insecta and Arachnida, contrasting strongly with them in regard to the legs, of which numerous similar pairs are present, though by no means so many as the names "centipede" and "millipede" would seem to imply. A common British centipede, the Thirty-Foot (*Lithobius forficatus*) (fig. 243), may be taken as a type. This is a small chestnut-coloured creature which lurks under stones or among loose earth, and glides rapidly away when disturbed. The body is flattened from above downwards, and is made up of a head and trunk, the latter consisting of sixteen segments, of which the first is extremely narrow, while each of the remainder bears a pair of jointed legs ending in pointed claws. The last two legs are much larger than the others, and turn sharply backwards. The narrow first segment of the trunk is provided with a pair of modified limbs, the bases of which are fused together, while each of them ends in a strong curved claw, near the end of which a poison gland opens.

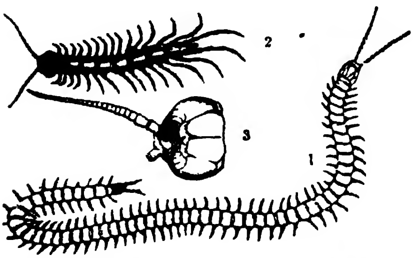


Fig. 243. British Centipedes: 1, (*Geophilus longicornis*). 2, 3, the Thirty-Foot (*Lithobius forficatus*). 3 is under side of head enlarged

The most obvious appendages of the head (fig. 244) are two long-jointed antennæ, while the remainder consist of three pairs of *jaws* guarding the opening of the mouth, and overlapped by the poison-claws. There is also a plate-like upper lip. The jaws, which are comparable in some respects to those of a cockroach (see p. 345), consist of a pair of hard-biting *mandibles*, followed by delicate flattened 1*st maxillæ*, and these again by leg-like 2*nd maxillæ*.

As in an insect, the breathing organs are *air-tubes* ramifying throughout the body, opening to the exterior on the sides by small holes (stigmata), of which the 3rd, 5th, 8th, 10th, 12th, and 14th leg-bearing segments each bears a pair. A group of *simple eyes* is to be seen on each side of the top of the head.

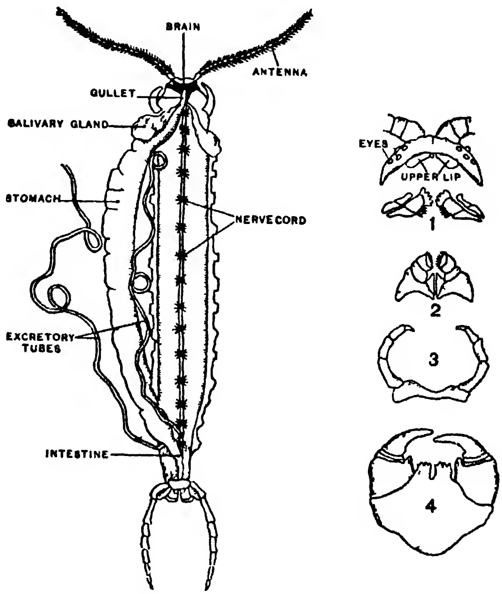


Fig 244 —Structure of Centipede

1, Mandibles, 2, first maxillæ; 3, second maxillæ, 4, first limbs of trunk, with poison claws

It will be seen from the above description that a Myriapod is decidedly simpler in structure than an Insect or average Arachnid, only the front part being clearly marked off as a head, while there is no distinction between thorax and abdomen, though the first segment of the trunk is specialized. The presence of numerous pairs of legs, extending right to the posterior end of the body, is also characteristic, there being no restriction of walking-legs to the front part of the trunk, as in a scorpion or cockroach, where there are no legs on the abdominal region. As in many other cases of animals with unspecialized trunk, there is considerable variation within the limits of the class as to the number of segments, and another noteworthy point is the similarity these segments exhibit among one another.

Myriapods are divided into the following five orders:—

1. Millipedes (CHILOGNATHA or DIPLOPODA)
2. Centipedes (SYNGNATHA or CHILOPODA).
3. Spider-legged Myriapods (SCHIZOTARSIA).
4. Insect-like Myriapods (SYMPHYLA).
5. Larva-like Myriapods (PAUROPODA).

Order 1.—MILLIPEDES (Chilognatha or Diplopoda)

Millipedes (fig. 245) are vegetarian Myriapods, devoid of poison-claws, and with cylindrical bodies. The legs are comparatively weak, and throughout the greater part of the trunk two pairs of them are borne by each segment, their bases being close together instead of wide apart, as in a Centipede. The antennæ are short and club-shaped, while each of them is made up of seven somewhat bell-shaped joints. The mouth is provided with a plate-shaped upper lip, strong mandibles, and two pairs of maxillæ fused together into a broad plate. There are two pairs of stigmata on each trunk-segment, and also two small pores (*foramina repugnatoria*), which are the openings of defensive stink-glands. The eyes resemble those of a Centipede in structure and position.

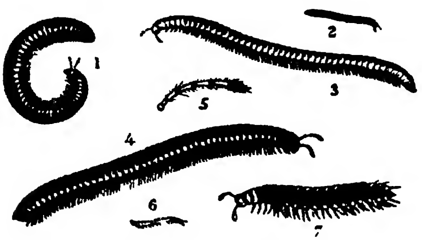


Fig. 245.—British Millipedes

1, London Snake Millipede (*Iulus Londinensis*). 2, 3, Spotted Snake Millipede (*Iulus guttatus*), natural size and enlarged. 4, 5, Earth Snake-Millipede (*Iulus terrestris*) and antennæ of same, both enlarged. 6, 7, Flattened Millipede (*Polydesmus complanatus*), natural size and enlarged.

Millipedes differ very much in length. A common British species of average length is the Earth Snake-Millipede (*Iulus terrestris*), a sluggish creature about an inch in length, commonly found under loose bark, &c., and with the habit of curling itself up when alarmed. The *Pill-Millipedes* are short forms which roll themselves into compact balls under similar circumstances. The genus *Glomeris* is represented by British species.

Order 2.—CENTIPEDES (Syngnatha or Chilopoda)

Centipedes conform in the main to the description already given of the common British form (*Lithobius*). The large Centi-

pedes of tropical countries, feared on account of their painful bite, constitute a widely-distributed family, including larger and longer forms, provided with twenty-one pairs of legs. Some of them may be as much as a foot in length. A well-known species is *Scolopendra morsitans.* Another family of Centipedes, found all over the world except in the coldest regions, includes slender elongated forms, which are devoid of eyes, and burrow underground in pursuit of earth-worms. Some of them are phosphorescent (fig. 243), as, *e.g.*, the common British species (*Geophilus longicornis*).

Order 3.—SPIDER-LEGGED MYRIAPODS (Schizotarsia)

Spider-legged Myriapods include the species of a genus (*Scutigera*) which is widely distributed through the warmer parts of the globe. The body is comparatively short, but antennæ and legs are very much elongated. The eyes are compound, a unique peculiarity in the class. The breathing organs differ considerably from those of ordinary Myriapods, and open to the exterior by a single row of stigmata placed in the middle line on the upper side of the trunk. They are very active creatures, and most of them pursue their prey in broad daylight, even when the sun is strong.

Order 4.—INSECT-LIKE MYRIAPODS (Symphyla)

Insect-like Myriapods include but one genus (*Scolopendrella*), of very small size, and represented by a number of widely-distributed species, of which two are British. The adjective "insect-like" is used on account of the very strong resemblance which exists to the primitive insects of the order Thysanura (p. 384), and some zoologists go so far as to state that we should look upon these forms as coming very near to the ancestral stock from which insects have been derived. There is at any rate a close relationship.

Order 5.—LARVA-LIKE MYRIAPODS (Pauropoda)

The order of Larva-like Myriapods includes certain exceedingly small creatures first discovered in Britain, and thought at first by their discoverer (Sir John Lubbock) to be larvæ.

The most remarkable character is found in the antennæ, which are branched. No breathing organs have, so far, been discovered. The type-genus is *Pauropus*.

CLASS 4.—PRIMITIVE TRACHEATES (PROTOTRACHEATA)

There are certain small groups of animals to which special interest attaches on account of the speculations regarding genealogy and origin of organs to which they have given rise. One such group is the Hemichorda, already briefly described (p. 300); another is the class now to be dealt with. It includes but a single genus, *Peripatus*, a primitive type which appears to be of great antiquity, and as the name of the class indicates, is supposed to represent the ancestral stock from which the air-breathing arthropods already described have been derived. The word "represent" must, however, as in such cases generally, be taken with some qualification, for Peripatus can only be regarded as representing that stock in a general sort of way, as no doubt it has to some extent specialized on lines of its own, acquiring peculiarities which adapt it to a special mode of life. To those who are not professed zoologists it may appear that specialists make an unnecessary fuss about an obscure creature that may briefly be described as a "permanent caterpillar"; but the marvel is explained when we remember that this lowly animal enables us to throw light upon the origin and relationships of Myriapods, Arachnids, and Insects, the last of which, taken by themselves, include the majority of terrestrial species.

Like many archaic forms, Peripatus has an extremely wide geographical distribution, and its included species are found in South Africa, the Malay Peninsula, East Australia, New Zealand, South America, Central America, and the West Indies. Yet all these widely-separated species resemble one another with sufficient closeness to be placed in the same genus.

Peripatus was first described (in 1826) as a Mollusc, later as a Myriapod and as an Annelid (segmented worm). The late Professor Moseley, in 1874, proved it to be an Arthropod, and our detailed knowledge of its structure and development is mainly due to the investigations of the late Professor F. Maitland Balfour and Mr. Adam Sedgwick. It is now a widely-accepted view that Arthropods have been derived from Annelids, and the special

interest attached to Peripatus centres in the fact that it, to use the words of Sedgwick, "stands absolutely alone as a kind of half-way animal between the Arthropoda and Annelida".

Peripatus (fig. 246) is a small cylindrical animal, found among rotting wood or the like, and comparable in appearance either to a well-nourished caterpillar or a segmented worm. The velvety *skin* is beautifully coloured, the tint varying according to the species. The front part of the body, called by courtesy the *head*, is not sharply marked off from the *trunk*, and this again is not clearly segmented, though its segmentation is indicated by the fact that it bears numerous pairs of stumpy *legs*, the exact number depending upon the species. These legs are hollow, conical projections (much like the appendages of some Annelids), and only exhibit in an imperfect way the jointing that characterizes Arthropods generally. Each of them is provided with a couple of sharp claws at its tip. Upon the under side of the head there is a swollen circular *lip* surrounding a depression within which the *mouth* opens. On each side of the head, outside this lip, is a short cylindrical projection known as *oral papilla*, and equivalent to a pair of modified limbs. Upon the tip of each of these is the opening of a large *slime-gland*, which secretes a sticky substance that can be forcibly ejected either as a defensive measure or else (in the New Zealand species at any rate) as a means of capturing prey. Within the circular lip are a pair of muscular *jaws*, each armed with two claw-like projections used for chewing the food. These jaws, again, are to be looked on as modified limbs, and the presence of such limb-jaws is an Arthropod character, though the limitation to a single pair is a peculiarity of Peripatus. A pair of cylindrical imperfectly-ringed *antennæ* project from the front of the head, and near the base of each of them there is a simple *eye*.

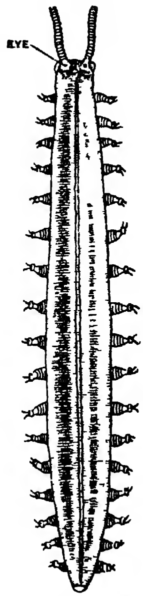


Fig. 246.--Cape Peripatus (*Peripatus Capensis*), enlarged

Only a few of the more important details regarding the *internal structure* (fig. 247) can be mentioned here, and these may be conveniently grouped into: 1. Arthropod characters, and 2. Annelid characters.

1. *Arthropod characters.*—The organs of *circulation* con-

form in the main to the type which has been described for the Cockroach (p. 348). The *heart* is a slender tube placed close to the upper surface of the body and suspended in a blood-containing pericardial space, from which blood passes into it through numerous pairs of valvular apertures. The rest of the blood-system consists of larger and smaller spaces which, together with the heart and pericardial cavity, make up a circulatory arrangement of which the parts communicate with one another.

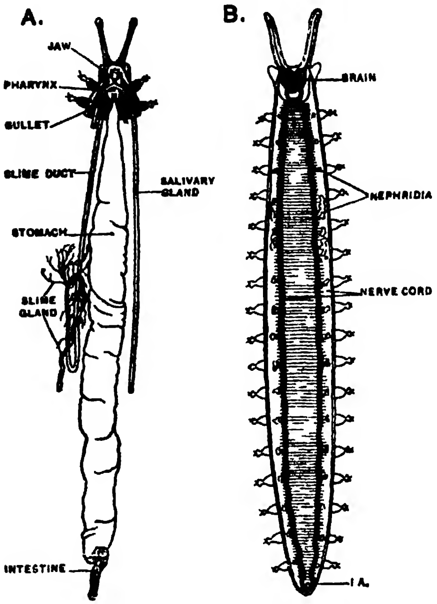


Fig 247 —Structure of Peripatus

A Digestive organs (from below) B Nervous system and excretory organs (from above). I.A Position of intestinal aperture (on under side).

This appears to be a suitable place in which to speak more fully of the nature of the Arthropod heart, which is essentially a blood-tube within a blood-space with which it communicates by paired apertures. In a Vertebrate (p. 40) or a Mollusc (p. 308) the heart possesses one or more *auricles*, into which blood is poured by veins, and the pericardial space surrounding it does not contain blood at all. Professor Ray Lankester explains the arthropod condition by supposing that the heart was originally a tube receiving blood by several pairs of lateral vessels which later on dilated into auricles where they joined the central tube. The fusion of these auricles into a large space round the heart would give the state of things now existing. The pericardial space of, say, Peripatus is therefore to be regarded, if the theory be well founded, as equivalent to a big auricle surrounding the heart; the physiological problem solved in this case being the evolution of an arrangement for storing blood about to enter the heart.

Peripatus further agrees with typical air-breathing Arthropods

in the character of its *breathing organs*, which are air-tubes. These are, however of very simple character, and open by very numerous stigmata scattered over the surface of the body and even present on the legs. The arrangement is not entirely irregular, for some of these apertures are placed in a double longitudinal row on the upper surface, while others are similarly disposed on the under surface. We have, on the whole, what may be considered a primitive or undifferentiated condition of these organs, from which it is easy to imagine the derivation of the more complex arrangements found in Myriapods, Arachnids, and Insects.

2. *Annelid characters.*—These will naturally be better appreciated after the Annelids have been considered, and will only be briefly enumerated.

The *body-wall*, like that of an ordinary segmented worm, consists of a thin skin covered by a delicate cuticle, and underlain by a muscular coat, consisting of an external layer of transversely-running fibres and an internal layer of fibres having a longitudinal direction. In regard to minute structure, the muscle-fibres differ from those of Arthropods in being devoid of transverse striations.

The mouth of Peripatus leads into a muscular *pharynx*, like that of many Annelids, but quite unlike what is to be found in Arthropods. A much more striking feature is to be found in the *excretory organs*. These consist of a series of tubes known as *nephridia*, one of which opens at the base of almost every leg, on its under surface. Such segmentally-arranged renal organs are extremely characteristic of segmented worms.

The *central nervous system* consists of a double brain- or cerebral-ganglion above the pharynx, and two ventral cords connected with these. A remarkable character is seen in the fact that these cords are widely separated except at the extreme posterior end of the body, where they unite together above the gut. Very numerous slender transverse nerves connect these two cords much as the rungs of a ladder connect its sides, though the "rungs" of the nervous system differ in being much more narrow and numerous. The nerve cords are dilated at regular intervals into ill-marked ganglia. This nervous system agrees with that of various Annelids, and is also much like that characteristic of the Proto-Molluscs.

Lastly, it may be noted that the eyes of Peripatus agree more closely with those of Annelids than with those of Arthropods.

B.—AQUATIC ARTHROPODS (BRANCHIATA)

The four Arthropod classes which have so far been reviewed, *i.e.* Insects, Arachnids, Myriapods, and Prototracheates, together make up the air-breathing or Tracheate division of Arthropoda; and we now come to the aquatic division, including the two classes of Crustaceans (Crustacea) and King-Crabs (Xiphosura), to which the Sea-Spiders (Pycnogonida) are doubtfully appended.

CLASS 5.—CRUSTACEANS (CRUSTACEA)

This very large class, of which a typical member, the Lobster, has already been partly described in contrasting Vertebrates with higher Invertebrates (p. 302), includes animals which are for the most part marine, though many, of the minute forms especially, inhabit fresh water, and some few are terrestrial.

So great is the diversity of structure within the limits of the class that no single type fully illustrates it; but it may be as well to enlarge somewhat upon the description already given of the Lobster (*Homarus vulgaris*), taking it as a good average example of the higher Crustacea. To those desirous of seeing how a single type may be made to illustrate the whole of the class in question, and at the same time give a sound knowledge of the principles of zoology generally, a perusal of Huxley's classic work, *The Crayfish*, is recommended.

External Characters of the Lobster (fig. 248).—The body is *bilaterally symmetrical*, and the hinder part of it, or tail, is clearly divided into *segments*. The front part of the body is a *cephalo-thorax*, consisting of head and thorax closely fused together, though segments are present here too, as shown by the numerous paired appendages. The *head* is marked off from the *thorax* by means of a distinct groove (cervical groove). The number of segments appear to be as follows:—head, 5; thorax, 8; tail or abdomen, 7. All the segments, and the appendages they bear, are constructed on the same common plan (see p. 195), but there are many differences in detail, to serve various physiological ends.

Appendages.—The letter Y may be taken as a diagram of the type on which the appendages are constructed, the stem of the letter corresponding to a basal stalk by which the appendage is attached to the body, while its two forks represent outer and inner branches. The same thing may be expressed in another way, by saying that the typical limb in a higher Crustacean is cleft or forked. We will now see how far the appendages of the Lobster conform to this Y diagram, and in doing so it will be convenient to start with the *abdomen*, as this is the least modified region. Of the seven segments here present only the first six bear appendages, while the last, usually known as the *telson*, forms the middle portion of the tail-fin. An average abdominal segment, say the fourth, bears two small forked appendages somewhat inappropriately termed *swimmerets*, and it will be seen from the diagram that these conform to the Y type. The appendages of the sixth abdominal segment are relatively large, and form the side-parts of the great tail-fin. Each of them, however, may be compared to a Y in which the main stem is shortened and broadened, while the two branches are flattened out into oval plates. It may further be noted that the first two pairs of abdominal appendages in the male are curiously modified, while in the female the appendages of the first abdominal segment are either absent or very much reduced.

Thoracic appendages.—The four hindermost segments of the thorax are stout *walking-legs*, of which the two first pairs end in small pincers. At first sight they deviate entirely from the Y type, for they are obviously not forked. This is a case where the facts of development are of use in throwing light on a problem, for we find that in a very young Lobster these walking-legs are forked, but their outer branches are comparatively feeble and ultimately disappear altogether. There is a further peculiarity about the three first pairs of these legs to which attention must be called, but before doing so it is necessary to speak of the nature and position of the breathing organs or *gills*. These are delicate plume-like outgrowths of the body, limited to the thoracic region, and sheltered in a gill-cavity on either side, the outer wall of which is formed by a firm gill-cover that constitutes the side of the *carapace* or hard shield covering the greater part of head and thorax. When

this gill-cover is cut away the gills will be seen, and it can readily be shown that they are of three kinds, attached to different regions of the body. It need only be mentioned here that some of them are *limb-gills*, so called because they are borne by the bases of certain limbs, among which are the three first pairs of legs. When one of these is carefully detached it will be seen that a thin plate (gill-plate) projects from its base, and that to that plate a feathery gill is attached. The fourth thoracic segment bears the most conspicuous appendages of all, *i.e.* the great *pincers*, which are constructed on the same lines as the nipper-bearing walking-legs, and like them are provided with gill-plates and limb-gills.

The three first segments of the thorax bear appendages modified for chewing, and called *foot-jaws*, the name suggesting the idea that they were once locomotor in function but have acquired new duties. The last or third pair of foot-jaws are decidedly leg-like, but are provided with stiff bristles where they bite against one another. An outer branch is present, though small, and gill-plate with limb-gill will be readily recognized. The middle or second foot-jaws are like the preceding, but a good deal smaller, while the first foot-jaws are very delicate, with broad biting basal stalk, small outer and inner branches, and gill-plate devoid of gill.

Head Appendages.—These consist of three pairs of jaws behind and two pairs of feelers in front. The jaws, beginning with the last pair, are named, as in an insect, second maxillæ, first maxillæ, and mandibles. The *second maxillæ* somewhat resemble the first foot-jaws, but gill-plate and gill are absent, while the outer branch is broadened into an oval "baler", which lies in the front of the gill-chamber, and by its constant scooping movement brings about a forward movement of water over the gills. The *first maxillæ* are still more delicate, and are reduced to a two-jointed basal stem and an insignificant inner branch.

The same parts are present in the first jaws or *mandibles*, but their proportions and texture are very different. The basal joint of the stalk is broadened into a hard biting-piece, strongly toothed on its inner margin, while the second joint of the stalk together with the inner branch make up a small three-jointed "palp" which probably has sensory functions.

Owing to an upward bend of the region in front of the

mouth, the two pairs of feelers are directed forwards, an advantageous position for sense organs of the kind. The second or smaller pair, the *antennules*, conform markedly to the Y-diagram, and consist of a basal stalk and slender outer and inner branches. But it is by no means certain that we are justified in comparing the parts of this appendage with those

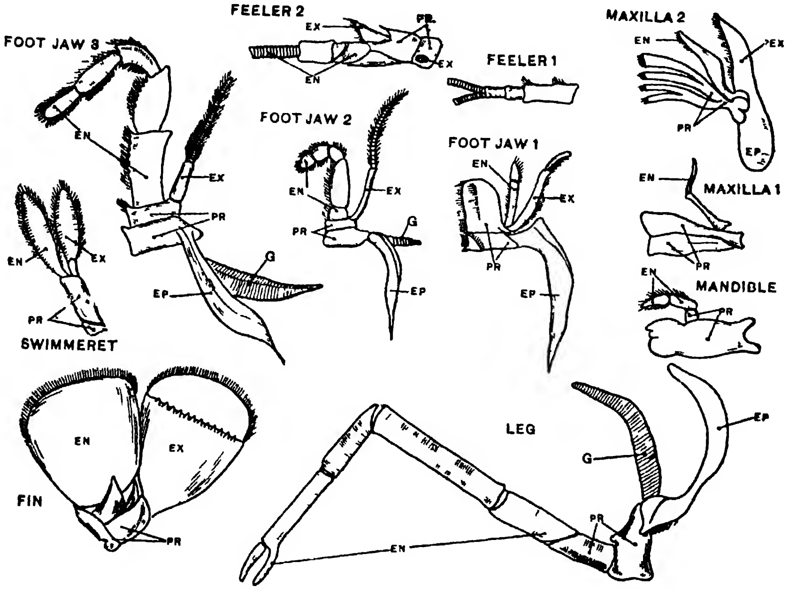


Fig 248 —Appendages of Lobster (*Homarus vulgaris*)

PR Base of appendage (protopodite) EN inner branch (endopodite EX outer branch exopodite), (the right hand EX in feeler 2 indicates excretory aperture EP gill plate (epipodite), G, gill

of the other ones, for it must be noted that the basal stem is here three-jointed instead of two-jointed as in all the other cases. The large feelers or *antennæ* conform to the type, for they consist of a two-jointed stalk, to which are attached a scale-shaped outer branch, and an excedingly long inner branch, which can be swept round so as to explore a considerable area in the neighbourhood of the body.

We have in the Lobster appendages an excellent example of the principles enumerated on p. 195, whereby structures of generalized type are modified in various ways to bring about special ends. These principles are: 1. variations in *shape*:

compare, *e.g.*, the antennæ, great pincers, and swimmerets; 2. variation in relative *size*: compare outer and inner branches in an average swimmeret and the side-pieces of the tail-fin; 3. variation in *number*: taking the Y-shape as the generalized type, the gill-plate is an addition in some cases, while in others the outer branch is much reduced or even absent; 4. *fusion* of parts: seen in the first abdominal appendages of the male.

This is a convenient point at which to compare some of the anterior appendages of Lobster with those of air-breathing Arthropods. One view is represented by the following table:—

Cockroach.	*Scorpion.*	*Centipede.*	*Peripatus*	*Lobster*
Antennæ	Absent.	Antennæ	Antennæ	Antennules
Absent	Chelicerae	Absent	Absent	Antennæ
Mandibles	Pedipalpi	Mandibles	Jaws	Mandibles
1st Maxillæ	1st Legs	1st Maxillæ	Oral Papilla	1st Maxillæ
2nd Maxillæ	2nd Legs	2nd Maxillæ	1st Legs	2nd Maxillæ
1st Legs	3rd Legs	Poison Claw	2nd Legs	1st Foot-jaws
2nd Legs	4th Legs	1st Claw	3rd Legs	2nd Foot jaws
3rd Legs	Operculum	2nd Legs	4th Legs	3rd Foot-jaws
Absent	Combs	3rd Legs	5th Legs	Great Pincers

It should be mentioned that many difficulties attend the comparison of segments and appendages in different groups, for one can seldom be quite certain that segments really correspond in different cases, and, even if they did, some appendages are apt to shift their position in the course of development.

The Lobster is protected by a firm shelly *exoskeleton* in the form of a horny layer which is thin where mobility is required, while elsewhere it is thick and hardened by the deposit of salts of lime. This strong suit of armour cannot increase in size as the animal grows, and the exigencies of the case are met by a process of moulting, which takes place frequently in young animals and at longer intervals later on. At the commencement of the operation a transverse split appears along the back, where the carapace joins the tail, and through this opening the animal painfully makes its way out. A sheltered corner is chosen for moulting purposes, and here the soft and defenceless creature remains till its new armour is properly developed and hardened.

The chief external characters have now been reviewed, and

the remainder may be taken in connection with the various systems of organs which are concerned, and which will be considered seriatim.

Digestive Organs (fig. 249).—These consist of (1) a symmetrical food-tube or *gut*, which runs back from the oval mouth situated on the under side of the head to the vent placed below the telson, and (2) of *digestive glands*. It will be noted that, as in Arthropods generally, the jaws are modified limbs, which work against one another from side to side and are entirely outside the mouth,

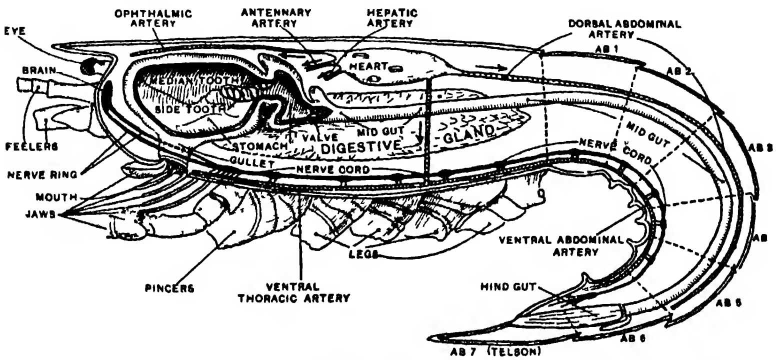


Fig 249.—Side-dissection of Lobster (*Homarus vulgaris*), reduced AB 1–AB 7, Abdominal segments.

which is bounded by upper and lower lips. It is found convenient to speak of the gut as being divided into three sections—a large fore-gut, a very small mid-gut into which the digestive glands open, and a long hind-gut. The distinction between these sections is based on the mode of development, for the first and last of them begin as pits which extend farther and farther inwards till they join the developing mid-gut, and form with it a continuous tube. It is not therefore surprising to find that the fore- and hind-guts, since they are formed by inpushing of the body-wall (see p. 261), are lined by a firm horny layer continuous with the exoskeleton, and that this layer is shed and replaced every time the animal moults. The *fore-gut* consists of a short *gullet* dilating into a very large *stomach*, divided into a cardiac section in front and a pyloric part behind. The stomach is said to be a "masticatory" one, for it contains a chewing apparatus or *gastric mill*, consisting of a number of hard pieces formed by thickening and calcification of the horny lining. These pieces

make up an elastic framework on which are borne two large lateral and one median tooth, and by the action of appropriate muscles these can be brought together so as to effectually chew anything that happens to be between them. The cavity of the pyloric part of the stomach is narrowed, and numerous interlacing bristles project from its walls, constituting a very effective "strainer", which prevents any but finely-divided particles from passing back into the short *mid-gut*. The lining of this part of the food-tube is soft, and a pair of large *digestive glands*, commonly called the liver, open into it. These organs are physiologically equivalent to liver and pancreas of a Vertebrate (see pp. 37 and 38). The *hind-gut* or intestine is a narrow tube continuous with the mid-gut, and possessing a firm lining raised up into longitudinal ridges.

The *Circulatory Organs* (fig. 350) conform to the Arthropod type already described in dealing with the Cockroach (p. 348), but the *heart*, instead of being a long slender tube, is a short broad sac, possessing only three pairs of valvular apertures, and suspended in the blood-containing pericardial cavity by means of fibrous cords. It is systemic (see pp. 308 and 348), *i.e.* contains purified blood, which it pumps through delicate branching arteries to the body at large. Sooner or later these arteries communicate with irregular spaces which ultimately open into a large *sternal sinus* running along the lower part of the body just within the body-wall. Meanwhile the blood has become impure by loss of much of its oxygen and receipt of carbon dioxide as a waste product. It therefore passes to the gills for purification, and, when this has been effected, is carried to the pericardial cavity, whence it passes into the heart through the valvular openings with which that organ is provided.

The *Excretory Organs*, by which nitrogenous waste is removed from the blood, consist of a pair of *antennary-* or *green-glands*, situated in the front part of the head and opening on the bases of the antennæ. Each is essentially a coiled tube, possibly equivalent to a nephridium (see p. 401).

The *Muscular System* is complex. The largest muscles are to be found in the tail, which is the organ by means of which the lobster is able to swim backwards through the water with great rapidity. Powerful *flexor muscles*, lying below the gut, bend the tail down and enable it to give its effective stroke, while

less powerful *extensor muscles*, lying above the gut, straighten it for another downward movement.

The Central Nervous System (fig. 249) consists of a *nerve-ring* surrounding the gullet, and a double *ventral cord* upon which numerous pairs of ganglia are developed. The upper part of the nerve-loop is thickened into a pair of brain or cerebral ganglia, by which the important sense organs of the head are supplied. The general arrangement conforms to that described in the Cockroach (see p. 349).

Organs of Sense are well developed, and many of them are in the form of specialized bristles or *setæ*, the soft axes of which are in communication with the skin by means of vertical canals which perforate the hard exoskeleton. Many of these setæ minister to the sense of *touch*, and this is especially true of those found on the antennules and antennæ. Organs of taste are not definitely recognized, though they probably exist on some of the appendages of the mouth. Certain peculiar spatula-shaped setæ present on the external branches of the antennules have to do with *smell*.

The extremely interesting *auditory organs* consist of two pear-shaped sacs, one of which is lodged in the basal joint of each antennule, and opens by a slit to the exterior. These sacs are really in-pushings of the skin, and they contain numerous specialized auditory setæ, and also grains of sand which have been introduced from the exterior. The chief interest attaching to these organs lies in the fact that they correspond to a stage in the development of more complex structures, such, *e.g.*, as the membranous labyrinths of Vertebrates, which start as pits in the skin (see p. 56)

The *visual organs* are in the form of two compound eyes situated on the front of the head near the antennules, and borne on stalks.

Development.—The Lobster passes through a *metamorphosis* in the course of its life-history, for it hatches out as a *larva*, which differs in many ways from the adult.

Crustacea, of which the Lobster has been described as a type, may be defined as aquatic Arthropods possessing two pairs of feelers (antennules and antennæ), and breathing organs (when such are present) in the form of gills. The appendages are typically forked. The class is subdivided in the following way:—

Sub-class 1.—Higher Crustacea (MALACOSTRACA).

Order 1. Stalk-eyed Crustacea (THORACOSTRACA).—Lobster, Cray-fish, Crab, Locust-Shrimp, Opossum-Shrimp, &c.

Order 2. Sessile-eyed Crustacea (ARTHROSTRACA).—Sand-Hoppers, Wood-Lice, &c.

Order 3. Intermediate Crustacea (LEPTOSTRACA).—Mud-Shrimps (Nebalia and its allies).

Sub-class 2.—Lower Crustacea (ENTOMOSTRACA).

Order 1. Barnacles (CIRRIPEDIA).—Ship-Barnacle, &c.

Order 2. Bivalve Crustacea (OSTRACODA).—Cypris, &c.

Order 3. Fork-footed Crustacea (COPEPODA).—Cyclops, Fish-Lice.

Order 4. Leaf-footed Crustacea (PHYLLOPODA).—Apus, Water-Fleas, &c.

Sub-class 1.—HIGHER CRUSTACEA (Malacostraca)

The following features, illustrated by the Lobster, are characteristic of the sub-class:—The body is made up of a constant and limited number of segments, each of which, with the exception of the last (or telson), bears a pair of appendages. In nearly all cases the segments are twenty in number, distributed as follows:—head, 5; thorax, 8; Abdomen, 7. The excretory organs typically present are antennary glands. The development is complex, and in most cases there is a larval form, differing markedly in appearance from the adult.

Order 1.—STALK-EYED CRUSTACEA (Thoracostraca)

In this order the head and thorax are fused together, and the eyes are usually situated on stalks. There are four sub-orders:—1. Ten-legged Crustacea (*Decapoda*), 2. Opossum-Shrimps (*Schizopoda*), 3. Locust-Shrimps (*Stomatopoda*), and 4. the Cumacea.

1. The *Decapoda* are so named because the last five pairs of thoracic limbs are seven-jointed locomotor organs, in which the outer branches are absent in the adult.

One large section of the sub-order is distinguished by the presence of a long and powerful tail, provided with a well-developed tail-fin. Among the British species here included are the following:—Lobster (*Homarus vulgaris*) (fig. 250), Rock-

Fig 250 —Mediterranean Crustacea

1, Lobster (*Homarus vulgaris*) 2 Bear Crab (*Scyllarus arctus*) 3 Dromia Crab *Dromia*)
4, Spider Crab (*Maia squinado*) 5, Locust Shrimp (*Squilla mantis*)

Lobster (*Palinurus vulgaris*) (fig. 251), Norway Lobster (*Nephrops Norvegicus*), Prawn (*Palæmon serratus*), Shrimp (*Crangon vulgaris*). The Crayfish (*Astacus fluviatilis*) is a fresh-water form.

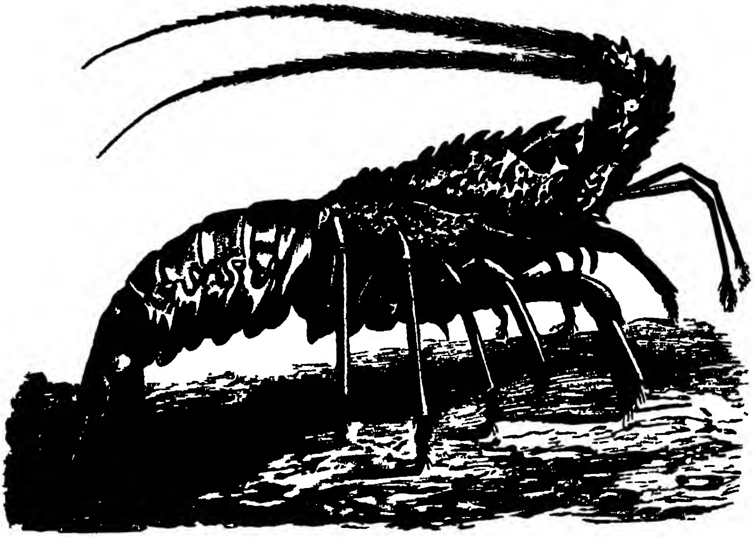


Fig 251.—Rock-Lobster (*Palinurus vulgaris*)

Another section, including forms intermediate between the above and Crab, is formed by the *Hermit-Crabs* (fig. 252), which take up their abode in the empty shells of various sea-snails, and possess a soft unsymmetrical tail that has lost most of its appendages except the last pair. These have lost their original function of acting as swimming organs, and are modified into hook-like structures, by which the hermit-crab holds on to its house.

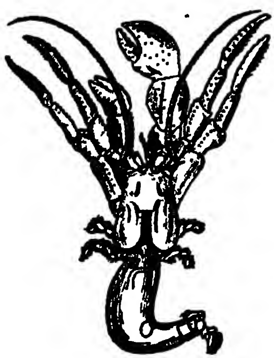


Fig 252.—A Hermit Crab (*Pagurus Bernhardus*), removed from its dwelling

The last section of the Decapods includes the true *Crabs* (fig. 250), in which the cephalo-thorax is very broad, and the tail so much reduced as to be useless as a swimming organ. Among British species may be noted the Edible Crab (*Cancer pagurus*) and the Shore Crab (*Carcinus mænas*).

2. The *Opossum-Shrimps* (Schizopoda) are small marine forms

often found swimming in large shoals, and superficially resembling ordinary shrimps, though of much smaller size. They differ, however, from these in many important particulars, among which may be mentioned the delicate nature of the shield covering the cephalo-thorax, to which at least one thoracic segment is not united. There are, further, eight pairs of closely similar thoracic legs, provided both with outer and inner branches. The commonest British genus is *Mysis* (fig. 253), which so closely resembles a

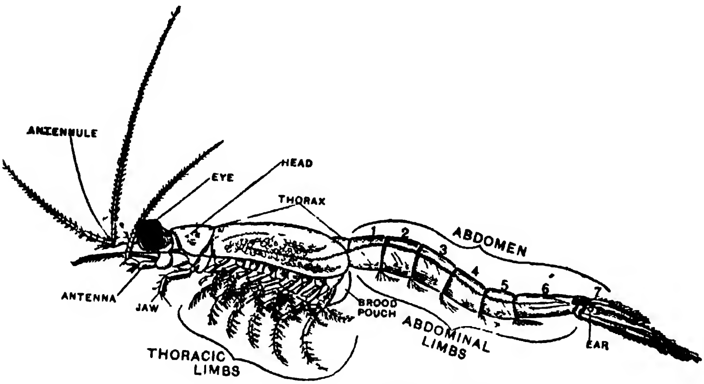


Fig 253 —Opossum Shrimp (*Mysis*), enlarged

stage in the development of the Lobster that this is spoken of as the "Mysis stage". Closed auditory sacs are present in its tail.

3. *Locust-Shrimps* (Stomatopoda) are much larger (fig. 250) than the members of the last sub-order, and are commonest in tropical seas, where they may attain a length of as much as 8 inches or more. The cephalo-thorax is small, for not only does it not include the last three thoracic segments, but it does not have to shelter the gills, as these are attached to the appendages of the broad well-developed abdomen. The thoracic appendages are remarkable, for the first five pairs of them are modified into foot-jaws, of which the second are extremely large and modified as seizing-limbs (fig. 250). So strikingly do they resemble the first pair of legs of the Praying Mantis (see p. 381), which have a similar function, that these Crustacea are often known as "Mantis-Shrimps". The last three pairs of thoracic appendages are leg-like, and possessed of both outer and inner branches. Two species are not uncommon in the Channel Islands (*Squilla Desmaresti* and *Squilla mantis*). Like

the other members of the sub-order, they are burrowing forms found in shallow water.

4. The sub-order *Cumacea* includes small shrimp-like forms (fig. 255) which live in shoals, and inhabit fairly deep parts of the sea where the bottom is of sand. The cephalo-thorax is even more

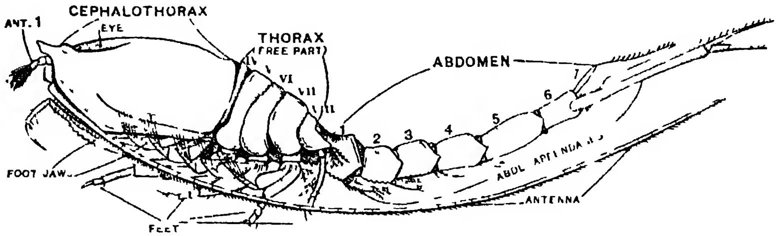


Fig. 254.—*Cuma* enlarged. ANT. 1, Antennule; IV–VIII, posterior thoracic segments; 1–7, abdominal segments.

limited than in the Locust-Shrimps, for the last five thoracic segments are not united with it. Some at least of the thoracic limbs possess outer as well as inner branches, and the two compound eyes are stalkless and sometimes fused together.

Order 2.—Sessile-eyed Crustacea (Arthrostraca)

The order includes a large number of comparatively small Crustacea, in which, as a rule, only one thoracic segment is fused to the head, and there is consequently no great armour-covered cephalo-thorax, as in a Crab or Lobster. The head-appendages correspond to those of a Lobster, but the thorax possesses only one pair of foot-jaws, its other appendages being seven pairs of legs, none of which are provided with pincers. There are usually six pairs of limbs on the abdomen. The eyes are devoid of stalks, *i.e.* are sessile

Two sub-orders are recognized, one containing laterally-flattened animals (Amphipoda), and the other forms which are flattened from above downwards (Isopoda).

1. The most typical members of the Amphipoda (fig. 255) are springing forms, of which the Sand-Hopper (*Talitrus locusta*) is a good example. During the summer months this may often be seen in leaping myriads between tide-marks on sandy shores. Its appearance suggests a strongly-curved flattened shrimp. Very similar in character are the species of the genus *Gammarus*, common in shallow water, both salt and fresh. The curious

Whale-Louse (*Cyamus ceti*) is exceptional among the members of the sub-order in having its body flattened from above downwards, and it is found parasitic on the skin of whales, to which it is enabled to hold fast by means of strongly-hooked legs. The abdomen is reduced to a mere stump entirely devoid of appendages. The weird-looking Skeleton Shrimps (*Caprella*) are also distinguished by the presence of a much-reduced abdomen. They are found climbing like monkeys among the branching colonies of various zoophytes.

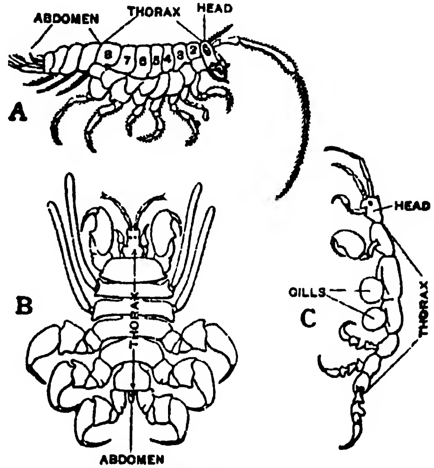


Fig 255 —Amphipods (enlarged)

A, Sand-Hopper (*Talitrus locusta*) 2 8, last seven segments of thorax, the first is fused with the head B, Whale-Louse (*Cyamus ceti*) C, Skeleton Shrimp (*Caprella*).

2. *Isopods* (fig. 256) differ from Amphipods in being flattened from above downwards, while the abdomen is shortened and bears plate-like appendages. Most of the species are marine, and of these *Cirolana*, *Idotea*, and *Sphæroma* may be taken as typical British genera Some, however, are fresh-water, as, *e.g.*, the common native Fresh-water Shrimp (*Asellus aquaticus*), distinguished by its long limbs; and still others are terrestrial, of which the most familiar is the Wood-Louse (*Oniscus murarius*), commonly found under damp stones and in similar places. Some of the Isopods are curiously modified to fit them for a parasitic life, and these will be mentioned elsewhere.

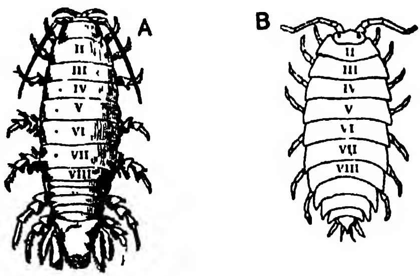


Fig. 256 —Isopods (enlarged)

II–VIII, Free segments of thorax, the first is fused with the head. A, *Cirolana borealis*, B, Wood-Louse (*Oniscus murarius*).

Order 3.—Intermediate Crustacea (Leptostraca)

The *Mud-Shrimps*, including *Nebalia* (fig. 257) and allied genera, form a restricted but interesting group of small marine shrimp-like creatures found in all parts of the world. These forms have attracted a good deal of attention, because they are a connecting-link between the higher and lower Crustacea, and some zoologists place them in a separate sub-class. Like the higher Crustacea they are composed of a definite and limited number of segments, in this case, however, twenty-one instead of twenty, for the abdomen has an extra segment, and the excretory organs include antennary glands. They also agree with stalk-eyed forms as regards their visual organs. But on the other hand all the segments of the thorax are free, though it and part of the abdomen are covered by a bivalve *shield* which grows back from the head, and the eight pairs of thoracic appendages are leaf-like, as in some of the lower Crustacea. The first four segments of the abdomen bear forked appendages as in certain other of the lower Crustacea (Copepoda), a further agreement with which is found in the fact that the tail also is forked. In addition to antennary glands they possess other excretory structures (shell-glands) resembling those of lower forms. On the whole it may be taken as fairly certain that the Leptostraca resemble in many points the ancestral stock from which the various groups of higher Crustacea have diverged.

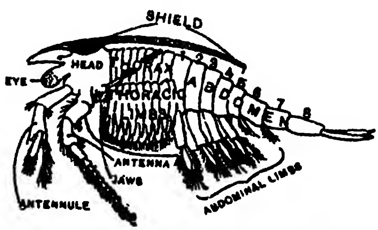


Fig. 257.—Mud-Shrimp (*Nebalia*), enlarged. Left half of shield cut away.

Sub-class 2.—Lower Crustacea (Entomostraca)

This is an exceedingly large and greatly diversified group, including both marine and fresh-water forms, of which the large majority are very small, and which play a very important part in nature as the food of higher animals. There is a very large amount of variation as regards the number of segments, and a similar wide range in the nature of the appendages, which are often flattened and leaf-like, though in other cases they may exhibit

the bifurcated type which we have found to be characteristic of higher forms. There is no gastric mill, and it is common to find three functional eyes present in the adult, two compound and one simple. As a general rule the embryo hatches out as a *Nauplius larva* (fig. 258), which typically possesses an unsegmented ovoid body and three pairs of appendages by means of which it swims, these corresponding to the antennules, antennæ, and mandibles of the adult. A larva of this kind is rarely found among higher Crustacea.

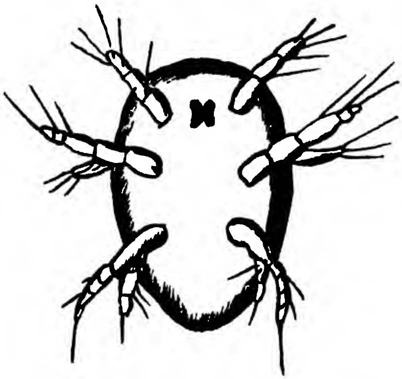


Fig. 258.—A Nauplius larva (seen from below and greatly enlarged) Note unpaired eye and three pairs of appendages

The four included orders have already been enumerated; *i.e.* 1. Barnacles (*Cirripedia*); 2. Bivalve Crustacea (*Ostracoda*); 3. Fork-footed Crustacea (*Copepoda*); and 4. Leaf-footed Crustacea (*Phyllopoda*).

Order 1.—BARNACLES (Cirripedia)

This is a remarkable group of marine Crustacea, all of which are either fixed or parasitic, and have undergone considerable, or, it may be, profound modifications resulting from their mode of life. Leaving out of consideration the degenerate parasitic forms, which will be dealt with elsewhere, there remain the widely-distributed group of Barnacles, of which the best known are the Ship-Barnacle (*Lepas anatifera*), and the Acorn-Barnacles (species of *Balanus*), which encrust the rocks between tide-marks on the coasts of Britain.

The characters of the group will best be understood by briefly describing the Ship-Barnacle (*Lepas anatifera*), large numbers of which are often found attached to floating objects which have been cast up on our shores, and which in old days were a serious nuisance to sailors, as they attached themselves to the wooden bottoms of ships in such vast numbers as to impede movement.

The *Ship-Barnacle* (fig. 259) is attached by means of a long soft *stalk* covered with corrugated skin, and upon this is borne a

flattened oval swelling, covered by a number of shelly pieces, suggesting at first sight that the animal is a kind of Mollusc. A closer examination will show that these pieces are attached to a couple of soft flaps united together on one side, but leaving between them on the other side a slit through which, in a living specimen, a bundle of hairy-jointed filaments will from time to time protrude and spread out, being drawn back again immediately afterwards. These tendril-like structures, or *cirri*, which act as a kind of casting-net, whereby food is swept into the mouth, are six pairs of bifurcated appendages, and their jointed nature shows that we are dealing, not with a Mollusc, but with an Arthropod. To a strong imagination they might suggest feathers in a vague way, and they are probably responsible for the well-known natural-history legend, according to which the Solan Goose ("Barnacle" Goose) develops from a barnacle, the chicks falling into the water when sufficiently grown to look after themselves. The specific name of the barnacle, "anatifera" (L. *anser*, a goose; *fero*, I bear), has reference to this old belief. On removing the shell, and the flaps to which it is attached, the soft body of the animal will be found, consisting mainly of *thorax*, to which the tendril-like appendages are attached. The *abdomen* is reduced to a limbless process ending in a long filament. The under (ventral) side of the thorax is turned upwards, and at its front end will be found the *mouth*, provided with upper lip, mandibles, and two pairs of maxillæ. No eyes or feelers are visible, but study of the development shows that the animal is fixed by its head, which has grown into a long stalk, at the end of which were situated the short antennules, that served as organs of attachment from which the sticky secretion of special "cement glands" was poured out. The antennæ, present in the larva, entirely disappear in the adult. Huxley has graphically compared a barnacle to a man lying upon his back and kicking his food into his mouth.

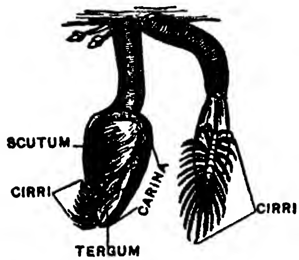


FIG. 259.—Ship-Barnacles (*Lepas anatifera*), reduced

Acorn-Barnacles agree essentially in structure with the ship-barnacle, but do not possess a stalk, and there is an extra protection to the body in the form of a sort of shelly cup made up

of a number of pieces fused together. The appearance of the body within the cup has no doubt suggested the name "acorn"-barnacle, but the resemblance is remote.

Order 2.—BIVALVE CRUSTACEA (Ostracoda)

These are small Crustacea common both in salt and fresh water, especially where the bottom is muddy. Examination of the mud from almost any pond will often reveal the presence of

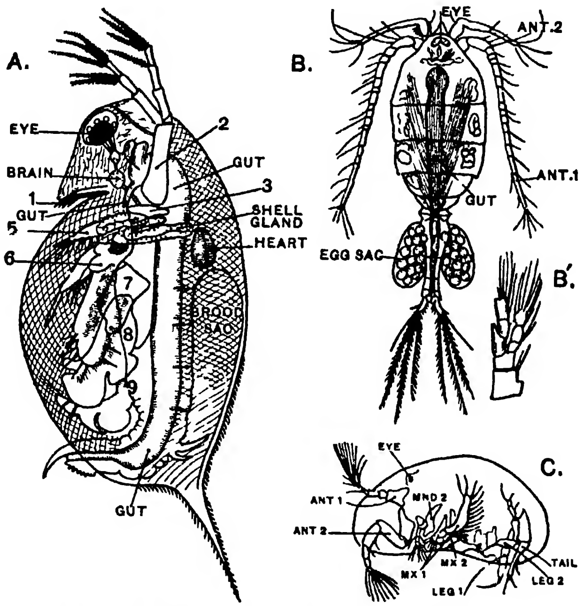


Fig 260—Small Fresh water Crustacea (much enlarged to various scales)

A, Water Flea (*Daphnia*) 1, antennule, 2, antenna 3, mandible 5–9, flattened thoracic appendages. B, Cyclops (seen from above) ANT 1, antennule ANT 2, antenna. B', Swimming foot of Cyclops, showing the typical forked shape C, Mussel Shrimp (*Cypris*) ANT 1, antennule ANT 2, antenna, MND, mandible MX 1, first maxilla MX 2, second maxilla

one or more *Mussel-Shrimps*, species of the typical genus *Cypris* (fig. 260), which therefore furnishes a convenient type. The most striking feature is the presence of a *bivalve shell*, comparable to the carapace of other forms and entirely enclosing the body, reminding one of the arrangement characteristic of bivalve Molluscs (p. 311). The resemblance is enhanced by the fact that the two valves of the shell can be closed by the contraction

of an adductor muscle and opened by the action of an elastic ligament. The body of the animal is extremely short, and the abdomen is a mere vestige. Segmentation is only indicated by the appendages, of which there are but seven pairs, five belonging to the head (two pairs of feelers and three pairs of jaws), and the remainder, in the form of narrow pointed legs, to the *thorax*. These legs can be protruded from the shell, and so can the well-developed feelers which are used as organs of locomotion, as in a nauplius larva. There is an unpaired eye on the front of the head.

Order 3.—Fork-footed Crustacea (Copepoda)

This order is a vast assemblage of species which are for the most part minute, and occur in all parts of the world both in salt and fresh water. Many of them are found in huge shoals at the surface of the open sea, forming a variety of *plankton*, as such assemblages are termed, which furnishes an important item in the food of whales and of many fishes, such as the herring. The fishes, however, do not have it all their own way with the Copepods, for attached to their eyes and gills may often be found parasitic members of the order, which are often strangely modified. Leaving such forms out of consideration for the present, and turning our attention to free-living Copepods, we may take a common fresh-water genus, *Cyclops* (fig. 260), as a type of the order. It can be distinguished with the naked eye as an active whitish creature with a jerky mode of progression.

The body of Cyclops has not unaptly been compared in shape to half of a split pear, with the convex side dorsal and the stalk corresponding to a tail. The body is distinctly segmented, and the five *head-segments* are fused with one another and with the first thoracic segment. Then follow the five free segments of the *thorax* and the four narrow segments of the *tail*, the last of which bears a *tail-fork* provided with two bunches of bristles. Upon the front of the head is a single reddish *eye*, which has suggested the generic name of Cyclops; and there are the usual five pairs of head appendages, of which the first, *i.e.* the *antennæ*, are very large and employed as oars. The thorax bears four large pairs of forked *swimming-feet*, and the abdomen is limbless. The female, which is the sex commonly seen, usually has a pair of large *egg-sacs* attached at the base of the abdomen.

Order 4.—LEAF-FOOTED CRUSTACEA (Phyllopoda)

These are Crustacea of varying size, though none are very large, which are for the most part inhabitants of fresh water. The segments and appendages differ greatly in number in different cases, but those of the latter situated farther back than the head are characterized by their flattened leaf-like form. There are two sub-orders—1. Gill-footed Phyllopods (Branchiopoda), and 2. Water-Fleas (Cladocera).

1. *Gill-footed Phyllopods* possess a special interest, since they not improbably present many of the characters distinguishing the ancestral stock from which all the different groups of Crustacea are descended.

A typical genus is *Apus* (fig. 261), species of which are sometimes found in great abundance at various localities on the Continent, especially in flooded meadows. For the sub-order this form reaches a considerable size, being as much as 2 inches in length. It is of a greenish-brown colour, and though segmentation is not apparent in the head, the rest of the body is composed of a large number of obvious segments. The most striking feature is the presence of a broad thin *carapace*, which, arising from the head, extends backwards so as to cover the back and sides of the greater part of the body. The narrow posterior end of the abdomen remains uncovered by the carapace, and terminates in a pair of long jointed filaments. The *head* bears a minute pair of antennules, vestiges of antennæ, strong mandibles, and two pairs of maxillæ. A very large number of flattened lobed swimming-feet are attached to the *thorax* and front part of the *abdomen*. They are not limited in number to one pair per body-segment, as is the case with the majority of Crustacea. A typical *swimming-foot* consists of a number of small pointed inner lobes, and two larger outer lobes, of which one is a soft

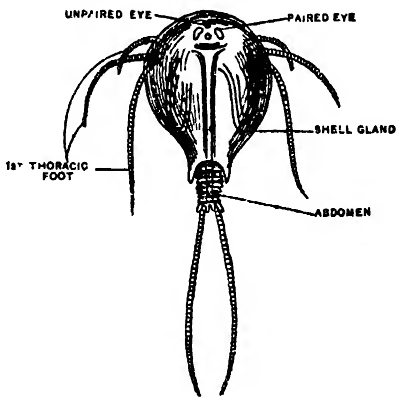


Fig 261—Apus

pear-shaped *gill.* Such a limb is regarded by many as the generalized type from which the varied kinds of appendages found within the class have been derived by modifications of different kinds (see p. 403). This may perhaps be so, but it is not always easy to recognize with certainty the equivalent parts in different Crustacean groups. All these swimming-feet in Apus are by no means exactly alike; *e.g.* some of the inner lobes of the first thoracic pair are drawn out into long filaments, liable at first glance to be mistaken for antennules and antennæ, while in the female the eleventh thoracic pair are partly modified into *brood-capsules* within which the eggs develop.

The *excretory organs* of Apus are not, as in the higher Crustacea, antennary glands, but coiled tubular *shell-glands* which open to the exterior upon the second maxillæ. Three *eyes* are placed close together on the top of the head—a small unpaired "nauplius eye" in the middle line, and a pair of compound eyes.

2. The *Water-Fleas* (Cladocera) are small active Crustacea, mostly inhabiting fresh water. The characters of the sub-order are well seen in the very common form *Daphnia* (fig. 260). The thorax and shortened abdomen are enclosed in a bivalve *carapace* which grows back from the head. The usual five pairs of appendages are borne by the head (except second maxillæ, which are absent), and of these the most remarkable are the large forked plume-like *antennæ* which are used as swimming organs. There are five pairs of flattened thoracic *swimming-feet*, something like those of Apus, but the short abdomen is limbless. It bends sharply round to the under surface and ends in a pair of curved bristles. When Daphnia is examined alive under the microscope, an oval pulsating sac will be noticed near the dorsal surface. This is the *heart.* The coiled *shell-gland* is also easily seen, and the large *compound eye* is a conspicuous object. It lies in the front of the head, and has been formed by the fusion of two lateral eyes. It is constantly in a state of trembling movement. A small *nauplius eye* is present a little farther back.

CLASS 6.—KING-CRABS (XIPHOSURA)

This small but interesting class includes only the *King-Crab* (*Limulus*), a large marine Arthropod living in shallow water in the East Indies and the warmer parts of the West Atlantic and

West Pacific. There has been much discussion as to its classificatory position, some authorities including it in the Crustacea and others in the Arachnida. In support of the latter view it has been shown that, allowing for the fact that one is a marine and the other a terrestrial animal, there is a very remarkable agreement between King-Crab and Scorpion. As, however, the matter is by no means settled, it appears better for the present to assign Limulus a class of its own.

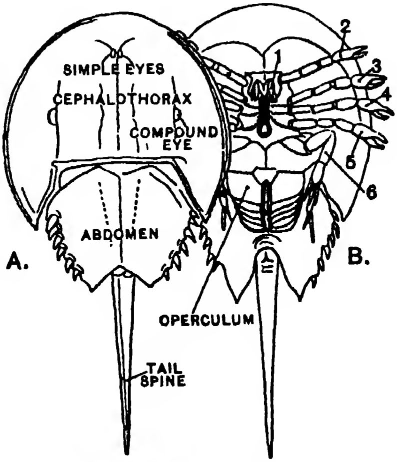


Fig. 262.—King-Crab (*Limulus*), reduced

A, From above; B, from below. 1, Chelicerae; 2–6, legs. The mouth is seen in B as a darkly-shaded slit between the bases of the legs

The body of a King-Crab (fig. 262) is divided into two regions, a *cephalo-thorax* covered above by a large horse-shoe-shaped shield, and a similarly protected *abdomen* to which a long movable *spine* is attached behind. A pair of *simple eyes* are situated on the top of the front shield towards the anterior end, and farther back there are a pair of large *compound eyes*, placed at a greater distance from each other.

Upon the under side the appendages can be seen, the first of which are the small *chelicerae*, provided with pincers and situated in front of the mouth. Then follow five pairs of *legs* apparently equivalent to the pedipalps and legs of the Scorpion. The first of them are provided with pincers in the female, and the next three pairs are similarly provided in both sexes. The ends of the last pair are curiously modified so as to fit them for digging. The bases of these leg-like appendages are provided with biting projections, which between them almost surround the elongated *mouth*. The remaining appendages are six plates, obviously formed by the fusion of pairs of appendages and borne by the abdomen. The first of them is equivalent apparently to the operculum of Scorpion (p. 386), and the second to the combs of that animal. All but the first bear numerous gill-folds.

CLASS 7.—SEA-SPIDERS (PYCNOGONIDA)

These are widely distributed marine Arthropods, mostly of small size. Some zoologists associate them with Arachnida, but their real affinities are as yet undetermined. Taking such a typical form as the Shore Pycnogon (*Pycnogonum littorale*), we see (fig. 263) that the spider-like appearance is due to the presence of four slender pairs of thoracic limbs, in front of which are three pairs of smaller appendages, of which the first bear pincers and the last are used by the males for carrying the eggs about. The mouth is situated on the end of an elongated snout, and there are four simple eyes.

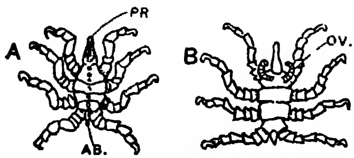


Fig. 263.—Shore Pycnogon (*Pycnogonum littorale*). A, From above, B, from below. AB Abdomen, OV. egg bearing appendages, PR snout

CHAPTER IX

STRUCTURE AND CLASSIFICATION OF SEGMENTED WORMS, SIPHON-WORMS, WHEEL-ANIMALCULES, MOSS-POLYPES, AND LAMP-SHELLS

SEGMENTED WORMS (ANNELIDA)

This phylum is a vast assemblage of marine, fresh-water, and terrestrial worms and leeches, which agree with one another in the possession of a bilaterally symmetrical body divided into numerous similar segments, and in the absence of jointed appendages like those of the Arthropoda. The body-wall consists of skin with underlying layers of muscle; there is a muscular pharynx; and the excretory organs are in the form of numerous pairs of convoluted tubes (nephridia), each of which, in typical cases, opens on the one hand to the exterior, and on the other into a body-cavity of the same nature as that found in Vertebrates (see p. 42). The phylum is divided into two classes: 1. Bristle-Worms (Chætopoda), and 2. Leeches (Discophora).

CLASS I.—BRISTLE-WORMS (CHÆTOPODA)

A good typical example of this group is the so-called *Sea-Centipede* (fig. 264), a name popularly applied to several species of the genus *Nereis* which are found upon our coasts. The body is bilaterally symmetrical and obviously divided into a large number of *segments*, all very similar to one another except those at the extreme ends. There are clearly none of the jointed lateral appendages which are so characteristic of Arthropods, their place being taken by hollow "foot-stumps" (parapodia), of which each segment bears a pair. The nearest approach to such foot-stumps among the Arthropoda are the legs of Peripatus (p. 399). Examination by means of a lens will show that each *foot-stump* is divided into an upper lobe and a lower lobe near each of which

is a short feeler or cirrus. Imbedded in each lobe is a bundle of bristles or *setæ*, of which one is much larger and stronger than the rest, though it only just projects from the surface of the body. These setæ are of great use in locomotion, acting as holdfasts by means of which the body gets a purchase on sand or the like. They exhibit all sorts of variations in shape. The *head*, upon the under side of which is the mouth, consists of a mouth-segment, and a projection in front of the mouth which may conveniently be called the head-lobe. From the upper side of this lobe, near the front, spring two short tentacles, and there are two much larger "palps" which arise from the under side of the same region rather farther back. Not only do these last-named structures act as sensory organs, but they also serve as lips to some extent. Upon the upper side of the head-lobe are four simple *eyes*, looking like black specks. The mouth-segment is provided with four pairs of slender feelers, which are apparently of the same nature as the cirri of the trunk-segments. None of the appendages are converted into jaws, a feature which is so characteristic of Arthropods, though it may be remembered that in the member of that group which comes nearest to the Annelida, *i.e.* Peripatus, there is only one pair of these structures (see p. 399). Turning now to the last tail segment, which is perforated by the opening of the intestine, we shall find that it is comparatively small and devoid of foot-stumps, though it possesses one pair of long backwardly-directed cirri.

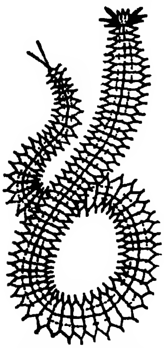


Fig 264.—A Sea-Centipede (*Nereis*), diagrammatic

Internal Structure of Nereis (fig. 265). The *body-wall* presents very primitive features, reminding one of Peripatus (see p. 401). It consists of the *skin*, which is practically little more than a thin epidermis covered by a tough cuticle, and two underlying *muscle-layers*, of which the outer is composed of fibres which run transversely, while the other consists of four prominent bands in which the fibres have a longitudinal direction. Closely connected with the body-wall, though scarcely perhaps forming part of it, is an oblique sheet of muscle on each side, made up of numerous fan-shaped sections, which take origin near the sides of the ventral nerve-cord and spread out in the foot-stumps, to which they are attached and serve to move.

Digestive organs.—On cutting open the body of Nereis we find that it is traversed by a straight *food-tube*, between which and the body-wall is a large *body-cavity* which corresponds with that of Vertebrates in being a cœlom, *i.e.* a body-cavity which contains a lymph-like fluid and communicates with the exterior by excretory tubes (see p. 428). The segmentation prominent externally is emphasized internally by the division of the body into a series of compartments by transverse partitions attached

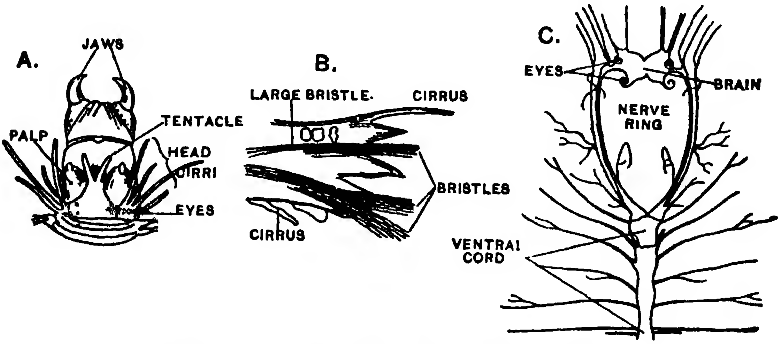


Fig 265.—Structure of Sea-Centipede (*Nereis*), enlarged to various scales
A, Head, with mouth-cavity everted and jaws protruding. B, A foot-stump (parapodium). C, Front part of nervous system

to the body-wall at the places where grooves mark off the segments from one another. These partitions are also attached to the gut, and keep it in place, thus acting like the folds known as *mesentery* in Vertebrates. The food-tube or *gut* consists successively of mouth-cavity, pharynx, gullet, and intestine. An interesting peculiarity of the short mouth-cavity is found in the fact that it can be everted, or turned inside out, by means of appropriate muscles, and under those circumstances the absence of limb-jaws is made up for by the protrusion of a pair of hard horny jaws carried on the inner side of the pharynx and acting as a very efficient pair of pincers for seizing food. The everted mouth-cavity is restored to its normal position by certain muscles attached to its wall which draw it back. The pharynx has extremely thick walls, another point in which one is reminded of Peripatus (see p. 401). The gullet is short and narrow, and a pair of glands open into it. The intestine, which makes up the greater part of the gut, is thin-walled.

Circulatory Organs.—We can here distinguish, as in a Verte-

brate (see p. 38), between a blood-system and a lymph-system. The *blood-system* contains red blood, the colour being due to the presence of the same pigment (hæmoglobin) as that found in Vertebrates (see p. 265), though here it is dissolved in the plasma, or liquid part of the blood, and is not contained in corpuscles. The vessels which carry the blood form a closed system, the smaller branches of which break up into capillary net-works. No heart is present, and the pumping is effected by the larger vessels, along which waves of contraction pass, forcing the blood onwards, much as digesting food is carried onwards in an intestine by peristaltic contraction (see p. 37). The two most important blood-vessels are longitudinal in direction, one being a *dorsal vessel* above the gut and the other a *ventral vessel* below it. The blood flows forwards in the dorsal vessel and backwards in the ventral one. From these two chief trunks transverse vessels are given off regularly in segmental order, and the branches of these break up into net-works in the substance of the various organs.

The *lymph system* consists of the body-cavity, and the colourless lymph which it contains consists of plasma in which float numerous irregular lymph corpuscles (see p. 42).

Respiration is effected in the body-wall, which is richly provided with blood-vessels branching just below the epidermis. Most likely the foot-stumps play an important part in regard to this function.

Excretion of nitrogenous waste is performed by the excretory tubes or nephridia, of which a pair are present in almost every segment. Each of these organs is essentially a ciliated tube which begins by a small funnel placed just in front of one of the partitions which cross the body-cavity, runs back to pierce this, and ultimately opens to the exterior on the under surface of the body close to the base of a foot-stump.

The *Central Nervous System* consists of a *nerve-ring* encircling the commencement of the gut and a *ventral nerve-cord*, resembling, therefore, the corresponding organs of a lobster. The nerve-ring is thickened dorsally into a closely-fused pair of brain- or cerebral-ganglia, and the ventral cord, which is of double nature, swells into a pair of closely approximated ganglia in each segment.

Sense Organs.—The cirri and head-tentacles are presumably organs of *touch*. It is likely that the palps borne on the head have to do either with *taste* or *smell*, or it may be with both.

There are no auditory organs, and the four simple *eyes* have already been mentioned.

The Bristle-Worms are subdivided into three orders:—1. Many-bristled Worms (Polychæta); 2. Few-bristled Worms (Oligochæta); and 3. Simple Segmented Worms (Archiannelida).

Order 1.—Many-bristled Worms (Polychæta)

This order embraces an enormous number of marine worms, possessing a considerable number of setæ and agreeing in many other particulars with Nereis, which is a type of the order. Over thirty families are recognized, grouped into seven sub-orders, but it will be sufficient for our purpose to divide the order into two groups:—1. Free-living Polychætes (Errantia), and 2. Sedentary Polychætes (Sedentaria).

1. *Free-living Polychætes* (Errantia), of which Nereis is a good example, are carnivorous forms which move actively about in pursuit of their prey, swimming, crawling, or burrowing. To this habit their structure corresponds, for the locomotor organs (foot-stumps) are well-developed, as also is the head-lobe, with its eyes and feelers. The pharynx can be protruded in the way described for Nereis and is usually armed with horny jaws.

Only one or two British forms can be mentioned here in addition to Nereis. Species of *Polynoe* are common on our shores, and these can readily be identified by their elongated oval form and the presence of a double series of scales (elytra) on the upper surface, which appear to be organs of respiration. Built on somewhat the same lines is the conspicuous "Sea-Mouse" (*Aphrodite*), the plump body of which attains a considerable size. The setæ are of several kinds, and very numerous: some of those arising from the upper divisions of the foot-stumps are much elongated and beautifully iridescent. As in Polynoe, there is a double row of elytra, but they are here covered by a tough membrane consisting of numerous small setæ matted together.

2. *Sedentary Polychætes* (Sedentaria) either have limited powers of movement, and inhabit permanent tubes, or else are burrowing forms, which pour out a sticky fluid from the skin that glues together the sand or mud surrounding them into a sort of temporary case. They live upon vegetable matter. The head-

region may either be much reduced and devoid of appendages, or else, in the forms inhabiting firm permanent tubes, provided with numerous tactile filaments and large branching gills. The foot-stumps are not so well developed as in the free-living forms, and the pharynx is not armed with horny jaws or teeth.

The *Lugworm* (*Arenicola piscatorum*) (fig. 266) is well known as a burrowing form highly esteemed as bait. It makes U-shaped passages in the mud or sand, near which may be seen coiled "worm-castings" made up of sand and undigested food, which have been voided from the body. The most striking external feature consists in the presence of branching *gills* projecting from the middle region of the body. *Cirratulus* is a long cylindrical worm often to be found buried in the sand underneath stones. Its locomotor organs are much reduced, and the dorsal cirri are slender elongated filaments which project above the surface of the sand and act as gills, the active wriggling movements which they constantly execute giving them a resemblance to small red worms, for which they are often mistaken. Another common shore form is *Sabellaria*, which glues sand-grains together into a tube. Large numbers of these animals live associated together, and their tubes often form compact masses of considerable extent. Every-one must have noticed at the sea-side small convoluted limy tubes encrusting oyster-shells or stones. These belong to *Serpula*, a particularly beautiful form, in which the head bears two brightly-coloured bunches of gill-filaments. One of these is converted into a conical horny stopper, which closes the opening of the tube when the worm has withdrawn itself. *Spirorbis* is a related but much smaller form, in which the tube is coiled into a flat spiral. Large numbers of these may often be found adhering to brown sea-weeds.

Fig. 266. Lugworm (*Arenicola piscatorum*)

Order 2.—Few-bristled Worms (Oligochæta)

These are segmented worms which for the most part live in fresh water or burrow in the earth. They lack feelers and foot-stumps, while gills are but rarely present. Locomotion is effected

by the contractions of the muscular body-wall aided by the setæ, which are comparatively few in number. The pharynx is not armed with horny jaws.

A common fresh-water form is the Red River-Worm (*Tubifex rivulorum*), a small creature often to be seen in ponds, partially imbedded in the mud. Large numbers often occur together, making up conspicuous red patches, that disappear when the mud is disturbed, which means that the worms have withdrawn themselves into it.

Earth-Worms are found in almost all parts of the world, and there are a number of British species, of which the Common Earth-Worm (*Lumbricus herculeus*) is usually taken as a type. The *head* consists of a mouth-segment and a head-lobe, and is entirely devoid of eyes or feelers. The *trunk* is divided into a large number of clearly-defined segments, and not very far from its front end is a band-like thickening, the *girdle* (clitellum), which has to do with the formation of capsules in which the eggs are enclosed. The popular notion is that it is the result of injury by the spade. If an earth-worm be passed, tail first, between the finger and thumb, a distinct feeling of roughness will be experienced, due to the presence of four double rows of setæ, the tips of which just project above the skin.

Order 3.—Simple Segmented Worms (Archiannelida)

A small number of simple marine worms constitute this order, and it is probable that to some extent at least they possess the characters of the ancestral stock from which all segmented worms are descended. It must not be forgotten, however, in this connection, that simplicity of structure is often the result of degeneration, and it is possible that some of these creatures may be on the down-grade. There is a small head-lobe, and most of them have a fairly long trunk. The segmentation of the body is well marked by the presence of encircling grooves, and also by rings of cilia, which serve as locomotor organs in place of setæ and foot-stumps, here entirely absent. Probably the most primitive of the Archiannelids is the minute *Dinophilus*, of which more than one species occur on our coasts. It presents certain points of affinity to the unsegmented worms, which will be considered later. *Polygordius* is a slender cylindrical red worm found,

among other places, in the Mediterranean, and also recorded from the British coasts. It is more complex in structure than Dinophilus.

A word of explanation may be here necessary of the statement that the simplicity of these creatures is possibly not primitive, but the result of degeneration. Take, for example, the absence of setæ as a character to be criticised from the two points of view. This negative character may mean that the ancestors of the group did not possess setæ, and, if so, the character is a primitive one. To maintain, on the other hand, that the absence of setæ is due to degeneration is to suppose that the ancestral forms did possess setæ, which have been lost in the course of evolution. That such a thing is possible becomes clear if we compare Nereis with some of the sedentary Polychætes and with earth-worms. In the first case well-developed foot-stumps provided with setæ are present; in the second, these structures are reduced; while ordinary earthworms possess setæ but no parapodia. A further reduction would give the condition found in Polygordius (and some Oligochætes).

Class II.—LEECHES (Discophora)

Leeches are typically fresh-water or terrestrial forms, though some of them are marine. Most of them are blood-sucking parasites. The average characters of the group are conveniently exemplified by the common Medicinal Leech (*Hirudo medicinalis*). The elongated body, capable of considerable variation in form, is flattened from above downwards, and is provided with a *sucker* at each end, by alternate attachment of which looping movements can be performed, much as in a looper caterpillar (see p. 364). Both the suckers face downwards, and the mouth is in the middle of the front one, while the intestine opens outside and just above the hinder one. Encircling grooves divide the body into a large number of narrow rings, several of which go to a segment. Feelers, foot-stumps, and setæ are entirely absent. Ten simple *eyes* may be seen as black specks on the front end of the body, placed close to the margin of the upper surface. The well-known three-rayed bite of the leech is made by the finely-toothed margins of three horny jaws with which the muscular pharynx is provided.

Although the Medicinal Leech does occur in this country, a

much commoner native form is the Horse-Leech (*Aulastomum gulo*), which has smaller jaws and does not attack animals, preying only upon small aquatic animals. Some of the Leeches do not possess jaws, and these are grouped in a special subdivision of the class. Many of them are parasitic upon fish.

SIPHON-WORMS (GEPHYREA)

This group is retained as a matter of convenience to include a number of worm-like animals, little known except to professed naturalists, and some of which appear to be related to Annelida. None of them exhibit other than feeble traces of segmentation.

The *Bristle-Tail* (*Echiurus*) (fig. 267) has a stout cylindrical body covered by tough skin. The *mouth* is situated on the under surface at the base of a narrow forward projection known as the *proboscis*, which must be regarded as a head-lobe. It is used both as an organ of locomotion and in procuring food, a deep groove running along its under side to the mouth. Among the characters which show affinity to the Bristle-Worms may be mentioned the possession of *setæ*, one or two rings of which encircle the hinder end of the body, while there are a pair of hook-like bristles imbedded in the skin not far behind the mouth. Behind them are the openings of two pairs of excretory tubes (brown tubes) comparable to the nephridia of segmented worms.

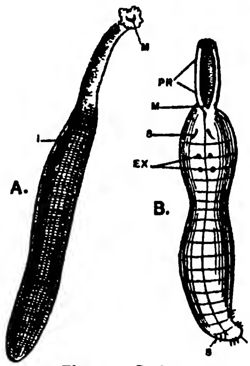


Fig. 267.—Gephyrea

Siphon-Worm (*Sipunculus*): M, mouth; I, intestinal aperture. B, Bristle-tail (*Echiurus*): PR, proboscis; M, mouth; S, setæ; EX, excretory apertures; I, intestinal aperture.

The *Siphon-Worm* (*Sipunculus*) (fig. 267), numbers of which are sometimes cast up on the shore by storms, burrows in the sand, which it swallows for the sake of the contained organic debris, in this respect reminding one of the earth-worm, to which also our native species have a slight external resemblance, though they differ markedly in the absence of setæ and body-segments. Examination of a living Sipunculus shows that the animal possesses the peculiar power of turning the narrow front part of its body outside in (introverting it), this and the reverse process often being rapidly repeated for a considerable number of

times. When the body is fully extended the *mouth* will be seen at its tip surrounded by a series of short, grooved *tentacles*. This creature departs further than Echiurus from the typical segmented worms, for it is entirely destitute of setæ, and the convoluted intestine opens to the exterior not far from the front end of the body on the upper surface.

WHEEL-ANIMALCULES (ROTIFERA OR ROTATORIA)

The Wheel-Animalcules are minute transparent animals mostly found in fresh water, though some are marine, and others are to be found on damp earth and vegetation. They present great diversity in form and structure, and as microscopic objects are unsurpassed for beauty and interest. Unfortunately their true affinities are yet to seek, but as likely as not they are the degenerate descendants of higher worms, and are to be looked upon as permanent larvæ, the original adult form having been dropped out of the life-history. That such a thing is possible is shown by the case of the Axolotl among Amphibia, to which reference has already been made (p. 249).

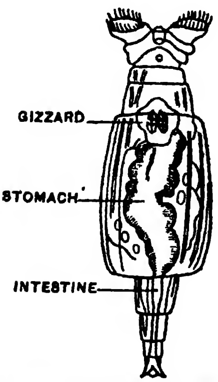


Fig 268 —Rose-coloured Rotifer (*Philodina roseola*), greatly enlarged

A common and beautiful fresh-water form, which will serve as a type, is the *Rose-coloured Rotifer* (*Philodina roseola*) (fig. 268). The elongated body is covered by a firm cuticle, and this is marked by transverse furrows so as to give a deceptive appearance of segmentation. The posterior end of the body tapers into a jointed tail ending in a pair of forceps, and by means of this region the animal is able to progress somewhat like a leech. When the rotifer is fully extended, a couple of prominences are seen at the front end which together constitute the *wheel-organ*. Each of them is fringed with a circlet of cilia, and as these move one after another in a very regular way a deceptive appearance of rotation is produced, suggesting the movement of a wheel. By means of this organ the animal is able to swim and it also sets up currents by which food particles are brought to the mouth, lying in a depression at the front end of the body. The *mouth*

opens into a mouth-cavity and this again into a muscular pharynx, which is continued by a short gullet into a wide stomach, this narrowing into an intestine which opens to the exterior on the upper surface of the body. Special interest attaches to the *pharynx*, usually known as the mastax, for the lining of this is thickened into a complicated set of hard pieces which work upon one another to crush the food. The transparency of the animal permits this process to be clearly seen, and it presents a curious and interesting spectacle, reminding one of the gastric mill in a lobster or the gizzard of a bird. The last section of the intestine is a *cloaca*, into which opens a thin-walled bladder (contractile vesicle) receiving nitrogenous waste matter from a couple of branched excretory tubes, which in some respects resemble the corresponding structures of the unsegmented worms. There are no specialized organs of circulation, these being represented simply by a fluid-containing body-cavity. *Respiration* takes place by the general surface of the body as is very commonly the case with minute animals of all grades. The *nervous system* consists of a comparatively large brain, placed in the front part of the body above the mouth. A red *eye-spot* is imbedded in its upper surface, and it is also connected with a stiff *dorsal tentacle* (calcar) which ends in a bunch of stiff hairs and is probably an organ of touch

Rotifers differ from one another in many respects. The general outline of the body varies largely, and the wheel-organ in particular may be very variously shaped. Sometimes the cuticle is thickened into a firm protecting carapace. Many members of the group are fixed, and in this case a cement-gland opens on the tip of the tail. Such forms often live in a cup or "house" of various nature. Some of these will be described later on, when the defences of animals are dealt with in detail.

MOSS-POLYPES AND LAMP-SHELLS (Molluscoida)

Considerable doubt attaches to the affinities of the two aquatic groups here associated together for convenience sake. They were originally included in the Mollusca. Milne-Edwards established "Molluscoidea" for Moss-Polypes and Tunicates, to which Huxley added Lamp-Shells. When, however, it was proved beyond doubt that the last group should without doubt be asso-

ciated with the Vertebrata (pp. 297–300), the term Molluscoida gradually fell into disuse, and the Moss-Polypes and Lamp-Shells were cut adrift. There is good reason for thinking that they are distantly related to the segmented worms, but their relationships to that group and to one another are very obscure. Perhaps the simplest plan will be to retain the old division Molluscoida for their reception, provided the derivation of the word (=mollusc-like) be ignored. As Huxley himself has remarked, it is often necessary to retain terms, the derivations of which have reference to obsolete views. The two included classes —1. Moss-Polypes (Polyzoa) and 2. Lamp-Shells (Brachiopoda)—are best considered separately.

CLASS I.—MOSS-POLYPES (POLYZOA)

These are small aquatic animals which are for the most part inhabitants of the sea, though some of them are found in fresh water. They present a peculiarity which so far we have only met with in some Tunicates (p. 300), *i.e.* they are *colonial.* From the egg a free-swimming embryo is hatched, which after a time becomes fixed and founds a colony by means of budding, in a way suggestive of what takes place in plants. The shape of the colony naturally depends upon the manner in which the buds arise, and it may be compact, flattened, or branched in a more or less elaborate way. There is a firm external skeleton for the support of the colony, sometimes of gelatinous nature, but more frequently of horny or calcareous consistency. Each member of the community (zooid) is lodged in a special depression or cup, and within the protective investment the bodies of the different zooids are connected together. The Polyzoa are among those animals included in the old group of "zoophytes" (Gk. *zōŏn*, an animal; *phyto*, a plant), so named from the exploded idea that they partook of the nature both of plants and animals, a notion largely due to the fixed nature and plant-like appearance of many kinds. Even yet some of them are popularly confounded with sea-weeds, and of such one of the most abundant is the Sea-Mat (***Flustra***) (fig. 269), the flattened branching skeletons of which are among the common objects thrown up on the shore by the action of the waves. Examination of one of these with a lens reveals the presence of innumerable closely-packed little cups,

the homes of the constituent zooids. Another common form is the Lace-Coralline (*Membranipora*), seen at low tide as a delicate lace-like encrustation upon the large brown sea-weeds.

Fig 269.—Polyzoa. 1, Sea-Mat (*Flustra*). 2, Sea Net (*Retepora*)

The structure of the group is most conveniently studied in one of the fresh-water Polyzoa, the *Plume Coralline* (*Plumatella repens*) (fig. 270), the branched creeping colonies of which are

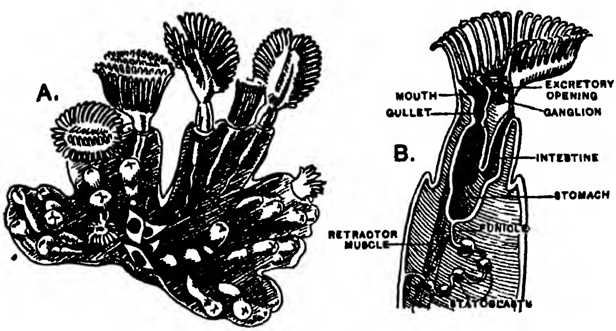


Fig. 270.—Polyzoa, enlarged

A, Small colony of *Lophopus crystallinus*, showing some individuals fully extended, and others in different states of retraction. B, Diagram of a single individual of *Plumatella*, cut through centre of body

found creeping upon stones and other objects. The *skeleton* is horny, and from the tip of each branch a zooid can be protruded, the free end bearing the *mouth* surrounded by a double crown

of ciliated *tentacles* in the form of a double horse-shoe, within the concavity of which is the external opening of the intestine. This protrusible part of the body is drawn back or introverted by a retractor muscle at the approach of danger, reminding one of the arrangement which obtains in Sipunculus (p. 433), a further resemblance to which animal is found in the approximation of the two openings of the gut, an obvious convenience in a tube-inhabiting animal. Within the translucent body the U-shaped *food-tube* can be clearly seen, consisting of gullet, stomach, and intestine. There are two small excretory tubes opening near the tentacular crown. The *nervous system* consists of a nerve-ring closely surrounding the beginning of the gullet, and thickened on the side next the intestine into a bilobed brain- or cerebral ganglion. The stomach is connected with the body-wall by a fibrous cord (*funicle*) in which are developed buds known as *statoblasts.* In winter the colony dies down, to be replaced in the following spring by fresh colonies to which these buds give rise.

Another very beautiful fresh-water form, the transparency of which makes it an attractive object under the microscope, is *Lophopus crystallinus* (fig. 270), in which the skeleton is gelatinous, and the entire colony, instead of being fixed, is able to creep slowly along the surface of water-plants.

Class II.—LAMP-SHELLS (Brachiopoda)

These are exclusively marine forms, including only about 120 recent species, though their area of distribution (which includes the British seas) is extremely wide. In some of the geological periods, however, they were extremely abundant, but have gradually declined in importance from very early times.

The most striking characteristic is found in the presence of a *bivalve shell,* which for a long time caused them to be confounded with bivalve Molluscs (pp. 328–338). Taking a typical *Lamp-Shell* (*Waldheimia* or *Terebratula*) (fig. 271) as an illustration, we shall find many well-marked differences from the members of the last-named group. To begin with, the two valves are not right and left, but upper and lower, and they are of unequal size, the upper being the smaller. In side view the shell resembles

in outline an ancient lamp, a fact which has given the popular name to the class. The projecting beak of the lower valve is perforated by a rounded hole from which projects a cylindrical stalk by which the animal is attached, and which occupies the same relative position as the wick of the imaginary lamp. The fixed sedentary habit of this and most other forms is another point of contrast with the bulk of bivalve molluscs, which possess a marked power of locomotion. We shall further find that either valve is bilaterally symmetrical, which is not the case with a shell of cockle, mussel, or the like, while the two valves of such a mollusc are typically equal in size. There are also great differences in the minute structure of the shell.

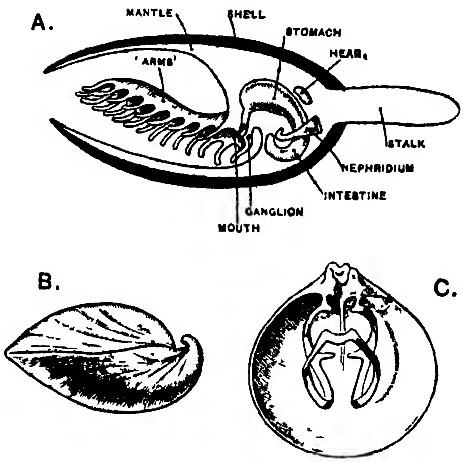


Fig. 271 – Lamp Shell (*Waldheimia*)

A, Diagram of structure, body cut through centre. B, Shell, seen from left side. C, Interior of dorsal valve, to show "carriage-spring" support for arms.

Upon opening the shell of a Waldheimia, the animal will be found to occupy but a very small proportion of the space within, but there are two large coiled "arms", one on either side of the mouth, fringed with a double set of *tentacles* and suggesting the tentacular crown of Plumatella, if one supposes the halves of this to be much elongated and coiled up. The so-called arms are supported by a curved loop, shaped like a carriage-spring and projecting from the upper valve. A mantle-lobe lines either shell.

In a bivalve mollusc the two halves of the shell are drawn together by adductor muscles and opened by an elastic ligament (p. 330). In a Lamp-Shell both processes are effected by muscles, and the hinge along which movements take place runs transversely and is placed close to the beak. The *gut* is a bent tube placed in the middle plane and consisting of gullet, stomach, and intestine, the last ending blindly. A good-sized digestive

gland opens into the stomach. The *excretory organs* are in the form of a pair of funnel-shaped tubes, which, like the nephridia of a segmented worm (p. 425), place a spacious body-cavity in communication with the exterior. The *central nervous system* essentially consists of a ring surrounding the gullet, and thickened above into brain- and below into other ganglia. (The upper part of the ring is not shown in fig. 271, A.)

CHAPTER X

STRUCTURE AND CLASSIFICATION OF FLAT-WORMS (PLATYHELMIA) AND THREAD-WORMS (NEMATHELMIA)

FLAT-WORMS (PLATYHELMIA)

The animals included in this phylum are unsegmented worm-like creatures which in most cases are markedly flattened from above downwards, hence the name of the group. They are divided into three classes:—1. Tape-Worms (Cestoda); 2. Flukes (Trematoda); 3. Planarian Worms (Turbellaria).

CLASS I.—TAPE-WORMS (CESTODA)

Tape-Worms are all internal parasites, and in the adult stage are almost without exception inhabitants of the food-tube in various Vertebrate animals, from Man downwards. The structure has undergone profound modification as a result of the parasitic habit, and the life-history is often complicated for the same reason. Details must be deferred till the phenomenon of parasitism is fully discussed, it being sufficient for the present purpose to briefly consider an average example of the group, the *Common Tape-Worm* (*Tænia solium*) (fig. 272), the adult stage of which is found in the human intestine. The long flattened whitish body has earned the name of "tape"-worm for the animal, which may be as much as 3 yards in length. It consists of a very small *head* and *neck* followed by the *trunk*, which gets broader and broader as we pass back to the hinder end, and is divided into a very large number of *joints*, which must not be mistaken for true segments such as have been described for annelids. It is indeed doubtful whether a tape-worm should be regarded as a single individual. An alternative view is that the head and neck together represent what may be called the primary individual, from which a long series of secondary individuals, the joints, has been originated.

Close examination of the minute *head* by means of a lens

shows that at its front end there is a double circlet of horny *hooks*, behind which four large *suckers* are arranged at equal distances. By means of these hooks and suckers the head is attached to the mucous membrane lining the intestine of the host. Such organs of attachment are common among parasites, and another example is given further on in the case of the Thorn-headed Worm (p. 449). No trace of a mouth can be seen, and indeed *digestive organs* are entirely absent, for the parasite lives at the expense of its host, absorbing through the general surface of its body the digested food with which, in the small intestine, it is surrounded. Nor are there any special *circulatory* or *respiratory organs*. The *excretory organs* are well developed and quite unlike the paired nephridia of segmented worms. They consist essentially of a narrow tube on each side, running not far from the edge of the body, and connected with elaborate branching canals which ramify in the soft substance filling up the spaces between all the internal organs. The *nervous system* is feebly developed, and its central parts consist of a longitudinal cord on either side, these being connected in the head by a transverse band, which may be regarded as equivalent to a pair of brain-ganglia.

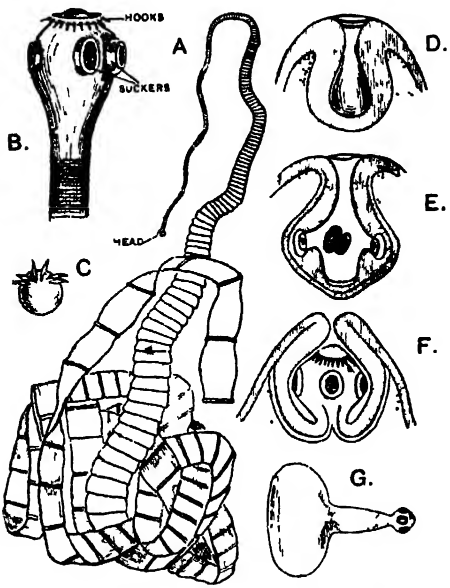


Fig. 272.—Common Tape-Worm (*Tænia solium*)

A, slightly reduced B–G, enlarged to various scales A, Adult, showing head and chain of joints (proglottides), the ripest of which have been broken off B, Head C, Six hooked embryo D–F, Stages in development of head G, Bladder-Worm stage (cysticercus), with head protruded

The *joints* which make up the trunk are largely filled with *egg-producing organs*, and, at the hind-end, joints full of ripe eggs are from time to time detached, passing out of the body of the host to the exterior. If any of these joints are devoured by a pig, the eggs hatch out in its stomach and the spherical embryos,

each of which is provided with three pairs of hooks, bore their way into the blood-vessels and are carried to the muscles, where they pass into a quiescent stage (pork "measles"). If a pig so infested is slaughtered, and some of the "measly" pork eaten in an imperfectly cooked condition by a human being, the life-history of the parasite is continued a step further, for the "measles" develop in the intestine of the new host into adult tape-worms.

Class II.—FLUKES (Trematoda)

Flukes, like Tape-Worms, are parasitic forms, but they present a wider range in the nature of their parasitism, some being found attached to the exterior of other animals, while some live within various organs of the host. Here again it will, for the present, suffice to describe a single member of the group, and the type which is most commonly taken as a sample is the *Liver-Fluke* (*Fasciola hepatica*) (fig. 273), a much-dreaded agricultural pest which gives rise to the disease of sheep known as "liver rot".

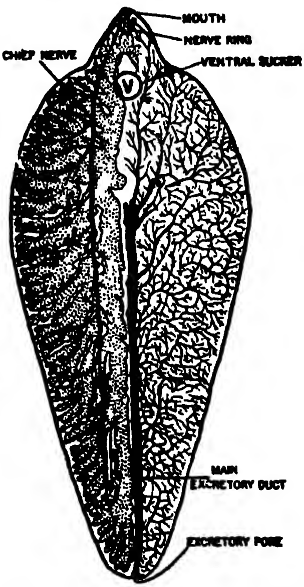


Fig. 273.—Liver-Fluke (*Fasciola hepatica*), diagrammatic

The adult Liver-Fluke is found often in large numbers in the liver of the sheep, or, in some cases, of other animals, among which Man must be included. The body is leaf-shaped and about an inch long. At the front end there is a conical projection on the tip of which is a *sucker* surrounding the opening of the mouth. There is a second sucker placed farther back on the under surface of the body, and the excretory organs open by a minute pore at the tip of the hinder end. The animal is covered by a thick *cuticle* beset with minute backwardly-directed spines, which facilitate an onward wriggling through the substance of the diseased liver, which gradually becomes more and more degenerated and broken down, till at last, in bad cases, the sheep dies.

The *internal structure* of the Fluke is extremely complex, and only a few of the more salient features can be mentioned. The *body-wall* consists of the cuticle with underlying epidermis and muscular layers, within which the spaces between the various organs is filled up by a soft packing material, much as in a tape-worm. Here, however, though special *circulatory* and *respiratory organs* are absent, the *digestive system* is well developed, for the surrounding food, consisting of blood and broken down liver substance, requires to be digested. The mouth leads into a muscular pharynx, acting as a suction-pump, this into an extremely short gullet, and this again into a forked intestine, the halves of which are much branched and end blindly. The *excretory organs* are much of the same kind as in the Tape-Worm, and the *nervous system* is not much better developed. It consists of a ring round the front part of the gut, thickened above into ill-defined cerebral ganglia, and giving off a number of nerves, of which the most important take a backward direction.

The *life-history* is more complex than that of the Tape Worm, and of a remarkable character, including a number of stages The ripe *eggs* produced by the adult Fluke may be taken as the point of departure. These pass down into the intestine of the sheep and thence to the exterior. If they happen to fall into water or on to damp grass, and fluke-disease is commonest in wet fields, an elongated *ciliated embryo* hatches out from each of them. This swims actively about for some time, and if it happens to come across a certain small water-snail (*Limnæa truncatula*), further stages in its life-history become possible. The larva makes its way into the lung of the snail and becomes a shapeless bag (*sporocyst*) within which are developed a number of cylindrical rediæ, constituting the next stage. The *redia* makes its way out of the sporocyst and travels to the liver of the snail, upon which it preys. The last stage in the life-history is the tadpole-like *cercaria*, which is really an immature fluke, and this is produced within the redia much as that took origin within the sporocyst. The cercaria leaves the snail, and, swimming through the water by means of its tail, reaches a piece of grass or some other plant, to which it becomes attached. The tail is lost and the body becomes invested in a firm limy coat or cyst. If now a sheep should happen to swallow one of these encysted forms, the limy covering is dissolved by the action of the gastric juice, and the young fluke, escaping,

passes on into the small intestine, whence it travels up the bile-duct into the liver, there becoming adult.

Class III.—PLANARIAN WORMS (Turbellaria)

These are widely-distributed flat-worms, differing from the members of the two preceding classes in being as a rule free-living, though a few are parasitic. All are carnivorous. Planarians are found abundantly in the shallower parts of the sea and in fresh water, while others are terrestrial, and are to be seen on damp earth and vegetation. One of the commonest British species is a fresh-water form, *Planaria lactea* (fig. 274). It is a flattened whitish creature of elongated oval shape, and an inch or less in length, which may be found gliding along over water-plants and stones. These movements are effected by a uniform covering of *cilia* with which the soft skin is clothed, and the presence of which constitutes one of the important differences from the Tape-Worms and Flukes. The ciliary action sets up minute currents and whirlpools in the surrounding water, which can easily be seen with a lens, and have given rise to the name Turbellaria, from the Latin *turbellæ*, a word vulgarly employed to denote the bustling of a crowd.

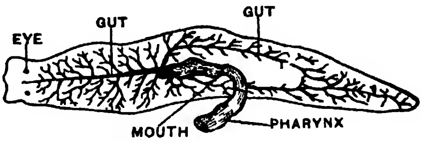


Fig. 274.—*Planaria lactea* (enlarged, with pharynx protruded to exterior

The front end of the body is comparatively broad, while the hind end is pointed. Upon the under side of the body, nearer the hind than the front end, is situated the *mouth*, which leads into a muscular *pharynx* continuous with a three-branched *intestine*, of which one section is directed forwards and the others backwards, while all three are beset with numerous branches that end blindly, reminding one of the condition of the digestive organs in a Liver-Fluke (p. 444). When the animal is in pursuit of prey. the pharynx is protruded from the mouth and used as an organ of capture, the food being taken directly into it, so, paradoxical as it seems, the mouth is not used as a mouth. As in Flukes and Tape-Worms there are muscular layers beneath the skin, and the spaces between the complex internal organs are filled up with packing material. As, too, in those forms there are no *circulatory* or *respiratory organs*, and the *excretory structures* are much of the same kind. The

central nervous system consists of a pair of brain-ganglia in the front part of the body, giving off various nerves, of which the two longest take a backward course. Upon the upper side of the head region are two simple *eyes*, each of which is provided with a lens and supplied by a special optic nerve.

The *Land Planarians* largely agree with the preceding in structure, but are much more worm-like in appearance, though equally unsegmented. Some of the tropical forms attain a large size (up to 18 inches when extended), and are brilliantly marked with longitudinal streaks of colour, but our few native species are dull in colour and insignificant in size. An example is *Rhynchodemus terrestris*, which is under an inch in length, whitish in colour below and dark-grey above.

The commonest example of the *marine Turbellaria* native to Britain is probably *Leptoplana tremellaris* (fig. 275), which is frequently to be found adhering to the under surface of stones between tide-marks. It belongs to a group which is exclusively marine, and differs in a number of important particulars from *Planaria lactea*. The flattened oval body is rounded at either end but considerably broader in front. Not only is the animal able to progress in the gliding manner already described, but it can also swim with considerable rapidity by flapping the sides of the body up and down. It then looks curiously like a minute Skate. The *mouth* is situated about the middle of the under surface, and the *pharynx*, when protruded from it, resembles a wide funnel with plaited sides. This region of the gut leads into an elongated oval *stomach* from which branching, blindly-ending tubes radiate in all directions. The bilobed *brain* is situated fairly far back, and gives origin to a number of radiating nerves. There are four groups of simple *eyes* situated on the upper side of the body, in the neighbourhood of the brain.

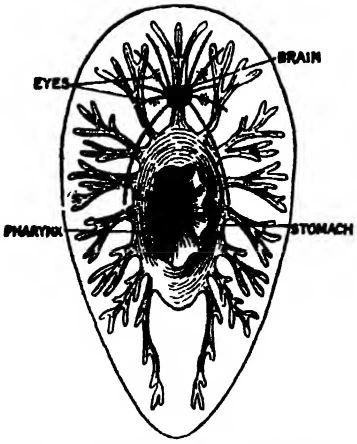


Fig. 275.—*Leptoplana tremellaris* (enlarged), as seen from under surface, with pharynx protruded to exterior

Certain Turbellarians belonging to the same group as the

species just described are brightly coloured, and some of them attain a large size, one recorded specimen being six inches long and four broad.

Speaking generally, the class of Turbellaria is one of extreme interest, for it contains the simplest animals exhibiting bilateral symmetry, and this is obviously associated with the creeping habit (p. 22).

THREAD-WORMS (NEMATHELMIA)

This phylum comprises an enormous number of unsegmented worm-like forms in which both ends of the body are usually pointed. The large majority of them are parasitic in the bodies of plants or animals, and various modifications in structure have taken place in consequence of this habit. A common and large type is the *Round-Worm*, one species of which (*Ascaris lumbricoides*) infests the human intestine, while a much larger species (*Ascaris megalocephala*) often abounds in the corresponding part of the horse.

The body of a Round-Worm (fig. 276), though cylindrical, exhibits bilateral symmetry, but not in so marked a manner as in the higher worms. Jaws and paired appendages of all kinds are entirely absent. The *mouth* is placed at the front end, and is guarded by three flap-like *lips*, of which one is dorsal, while the interspace between the other two is in the mid-ventral line. Each side-lip bears a small papilla which probably has to do with touch, and two of these are to be found on the dorsal lip. The intestine opens on the under side, not far from the hinder end, which in the male is sharply bent round. Close examination shows the presence of four streaks running longitudinally along the body and corresponding to special modifications of the body-wall. Two of these streaks are the *lateral lines*, one on each side, and the others are *dorsal* and *ventral lines*, running in the median plane above and below respectively.

The *body-wall* resembles that of a Nereis (p. 426) in so far that it consists of external cuticle with underlying epidermis and muscle, but the differences in detail are very considerable. The cuticle is very firm and strong, probably serving to protect the animal from the digestive juices of its host, while the epidermis is indistinct and projects inwards to form the lateral and median

lines. As a result of this, the underlying muscle, which constitutes a sort of longitudinal layer, is broken up into four sections.

The *digestive organs* (fig. 276) consist of a narrow tube running straight through the body, beginning with a thick-walled gullet which passes into a thin-walled intestine. Between the gut and body-wall is a body-cavity containing fluid, but there is nothing else to which the name of circulatory system can be applied. There are no special breathing organs, and the *excretory organs* are quite unlike those of a segmented worm (p. 428), consisting as they do of a narrow tube running in each lateral line, and joining with its fellow in front to open by a minute pore on the under surface. The *nervous system* again is in many respects unlike that of a segmented worm (p. 428). It is closely connected with the skin, and its most conspicuous portions consist of a ring not far behind the mouth, from which nerves are given off both fore and aft. Those in front supply the lips, and of the others the largest are a dorsal and a ventral nerve which traverse respectively the dorsal and ventral lines.

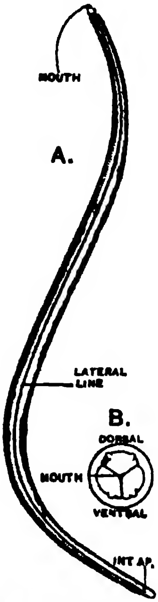


Fig. 276.—Round-Worm (*Ascaris*)

A, Side view; B, front end of body, much enlarged to show mouth and lips. INT. AP., intestinal aperture.

A common example of free-living Thread-Worms is the little Vinegar Eel (*Anguillula aceti*), common in paste and weak vinegar. Another curious creature, representing a group differing in many respects from the one containing Ascaris and Anguillula, is the Gordian-Worm (*Gordius*). This is a very slender black worm, often to be seen in pools or puddles, and the name has reference to the fact that a number of them may often be found twined together into a complicated tangle. In early life the Gordian-Worm is parasitic in an insect, leaving its host, however, when it becomes adult, and as large numbers do this about the same time, their appearance in public is somewhat sudden. Hence the rustic belief, once prevalent, that they have been rained down from the sky, a common explanation of the rapid appearance in any quantity of all sorts of small animals. Another curious popular idea, suggested by the appearance of the worms, is that they are horse-hairs into which the breath of life has mysteriously entered.

A small group, provisionally placed in the Thread-Worms, is that represented by a curious parasite the Thorn-headed Worm (*Echinorhynchus*), the front end of which is provided with a hook-studded projection, by means of which attachment to the lining of its host's intestine is effected. There are very many structural differences from such a typical form as the Round-Worm, the most remarkable being the absence of digestive organs, and it is more than doubtful whether the group should be included in the Thread-Worms at all. A typical species (*Echinorhynchus gigas*) lives, when adult, within the digestive organs of the pig, while its larval life is spent within the body of a Rose-Chafer or other related beetle.

CHAPTER XI

STRUCTURE AND CLASSIFICATION OF ECHINODERMS (ECHINODERMATA)

This is one of the most sharply-marked phyla in the animal kingdom, having specialized on very distinctive lines. Though considered after the flat-worms, it must not be imagined that it occupies a lower place in the scale. Indeed, as explained earlier (p. 11), it is impossible to place the various groups of animals in a linear series, each member of the series higher than the one next below it, and lower than the one next above it. But it is clearly necessary to describe the groups one after the other, just as if they actually formed such a series, and this is apt to give misleading ideas.

The phylum contains marine animals only, and probably the most familiar of these is the Common Star-Fish (*Uraster rubens*), found in abundance on many parts of our coast. It will serve very well as our illustrative example.

The body of a Star-Fish (fig. 277) is built on a plan quite different from those exhibited by the bilaterally symmetrical animals with which we have so far been concerned. As in a very large number of marine Invertebrates, there is a free-swimming larva, known in this case as a Bipinnaria, which is markedly bilateral. It is converted into the adult stage by a very complicated series of changes, constituting a true *metamorphosis*, one result of which is that the original bilateral symmetry becomes obscured, being replaced by a simpler kind of regularity to which the name of *radial symmetry* has been given, and which is well exemplified by the flower of a primrose, a cart-wheel, or a regular pentagon. In one kind of Star-Fish, indeed (*Goniaster*), the body is a pentagonal disc, but in the form selected for description, the corners of the pentagon have, so to speak, been drawn out so that a distinction can be drawn between a central *disc* and five radiating *arms* which are continuations of it. In a Vertebrate, Arthropod,

or Worm, the body can be divided into corresponding halves in one way only, *i.e.* by a median plane which separates the right side from the left, but here this can be done in five different ways. Another way of putting it is to say that the body is regularly built up around a series of axes which radiate from a common central point. Any part or organ which is cut by one of these axes may be said to occupy a *radial* position, while *interradial* structures

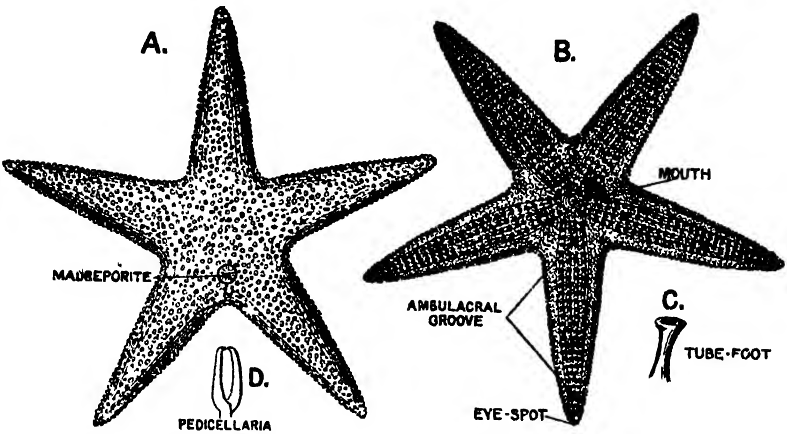


Fig. 277.—Common Star-fish (*Uraster rubens*).
A and B. Upper and under surfaces, reduced. C and D, much enlarged.

fall between adjacent axes. There is, it is true, a distinction between upper and lower surfaces, as in vertebrates, &c., but it is by no means clear that we are justified in considering these to be truly dorsal and ventral.

Turning our attention to the pale under surface, we shall see, in its centre, the *mouth*, entirely devoid of jaws and placed in the middle of a soft area from which a deep groove runs along each arm to its tip. Occupying these five grooves are a large number of slender cylindrical structures which observation of a living star-fish shows to be used in locomotion, and which have consequently been termed *tube-feet*. Each groove has fancifully been termed an *ambulacrum*, because, together with its tube-feet it suggested to the giver of the name a little pleasure grove or tree-lined avenue (Lat. *ambulacrum*). The tips of the arms are commonly seen to curl upwards, and each of them bears a reddish *eye-spot*.

The most conspicuous feature of the upper surface of the disc is found in the presence of a rounded plate in one of the interradial areas. The meandering grooves which mark its surface look like the markings upon certain corals (madrepores), and have suggested the name of madreporic plate or *madreporite*. As there is only one of these structures, the radial symmetry of the body is interfered with, and, strictly speaking, it is bilaterally symmetrical, the median plane passing through the plate and along one arm, which is generally considered to be the front or anterior one. So that the Star-Fish really presents bilateral symmetry masked by radial symmetry, so to speak. The minute aperture of the intestine is placed near the central point of the upper surface, but is not absolutely in the centre.

The Star-Fish is firm to the touch, owing to the presence of a well-developed system of hard *calcareous plates*, present in the deeper part of the skin, and which are best seen in a dried specimen. Those which support and strengthen the upper part of the body are united together into an irregular net-work, but in the neighbourhood of the ambulacra they are regular in shape and have a definite arrangement. Of these plates the most conspicuous are a double series of ambulacral ossicles united together so as to look, in the cross section of an arm, like an inverted V. The edges of the ambulacra are fringed with *spines*, and it is the presence of these in typical Echinoderms which has given the name to the phylum (Gk. *echinos*, a hedgehog; *derma*, skin). Spines, however, are much more numerous and conspicuous in the members of some of the other sorts of Echinoderm, notably in the Sea-Urchins, which is expressed in the name for "urchin", an old English word for a hedgehog. Among these spines, especially in the neighbourhood of the mouth, are some which have been peculiarly modified to form snapping jaw-like structures, known as *pedicellariæ*. One use of these is probably to assist in cleaning the surface of the animal.

Internal Structure (fig. 278).—Several points of interest are presented by the *digestive organs*. The *mouth* leads into a large *stomach* with folded walls, capable of being protruded outside of the body so as to engulf prey of comparatively large size. Star-fishes are extremely rapacious animals, and are among the worst enemies of the oyster. The stomach, after protrusion, is drawn back into the body by special muscles. It is continued into a

five-angled *pyloric sac*, and this into a short thin-walled *intestine*. The cavity of each arm is largely occupied by a pair of large saccular tubes which open into one of the corners of the pyloric sac, and secrete a digestive juice. The *circulatory organs* chiefly consist of an ill-developed blood-system devoid of heart, and of a spacious body-cavity. Special *respiratory organs* are evidently necessary in a creature furnished with a firm exo-skeleton, and in this case the function is discharged in part by delicate branched gills which can be protruded through the interstices of the calcareous net-work which strengthens the upper

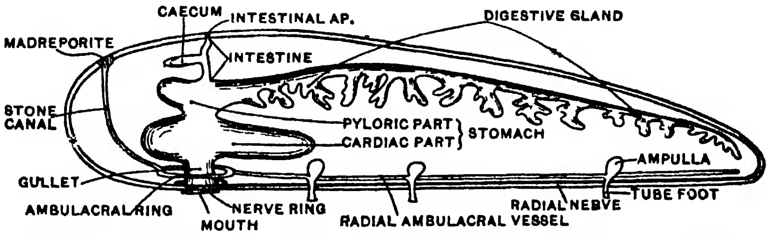


Fig. 278.—Common Star-Fish (*Uraster rubens*), cut through disc and one arm to show structure Diagrammatic

surface. The tube-feet most likely help in breathing, and some of them in the neighbourhood of the mouth appear to be specially concerned with this function.

Great interest attaches to what is known as the *water-vascular system*, a set of organs to which the tube-feet belong, and which is quite unlike anything existing in other subdivisions of the animal kingdom. It consists of a tubular *ring* surrounding the beginning of the food-tube, and sending a *radial vessel* along each arm, just below the union of the two rows of ambulacral ossicles. The *tube-feet* are branches of the radial vessels, but they are also connected with little transparent bladders (ampullæ) placed within the cavities of the arms. The fluid filling the water-vascular system is largely sea-water, which is able to get in from the exterior by a *stone-canal* that runs from the madreporite to the central ring, the grooves in the former being perforated by numerous minute holes. The ampullæ, by their contraction, force fluid into the tube-feet, thus causing their protrusion. This method of working a set of locomotor organs is quite unlike anything we have so far met with, and it compensates for the comparative feebleness of the *muscular system*, correlated,

it would seem, with the marked development of a continuous exoskeleton, between the parts of which there are not, as in Arthropods, well-marked joints permitting of free movement.

The *nervous system* is of very primitive type, and arranged, like the other internal organs, in accordance with the radial symmetry of the animal. It is intimately connected with the skin, of which, in fact, it may simply be regarded as a thickening, and its best-marked portions consist of a *ring* round the mouth, and five *radial nerves*, one of which runs along each arm. But the entire body is invested in a nervous sheath, consisting of a delicate net-work lying in the deeper part of the skin. The chief *sense organs* are the tube-feet, which appear to be, among other things, tactile structures—indeed there is an odd tube-foot at the end of each arm which may definitely be called a tentacle,—and the *eye-spots* already noted.

What are known as "comet" forms of Star-Fish are not infrequently met with, *i.e.* specimens in which from one to four arms are smaller than the remainder. The small arms are new ones growing in place of others which have accidentally been lost. Lower animals often possess considerable powers of regenerating mutilated parts, and this is to a limited degree the case even among some of the Vertebrates.

Living Echinoderms are arranged in five classes:—1. Star-Fishes (Asteroidea); 2. Brittle-Stars (Ophiuroidea); 3. Sea-Urchins (Echinoidea); 4. Sea-Lilies and Feather-Stars (Crinoidea); Sea-Cucumbers (Holothuroidea).

Class I.—STAR-FISHES (Asteroidea)

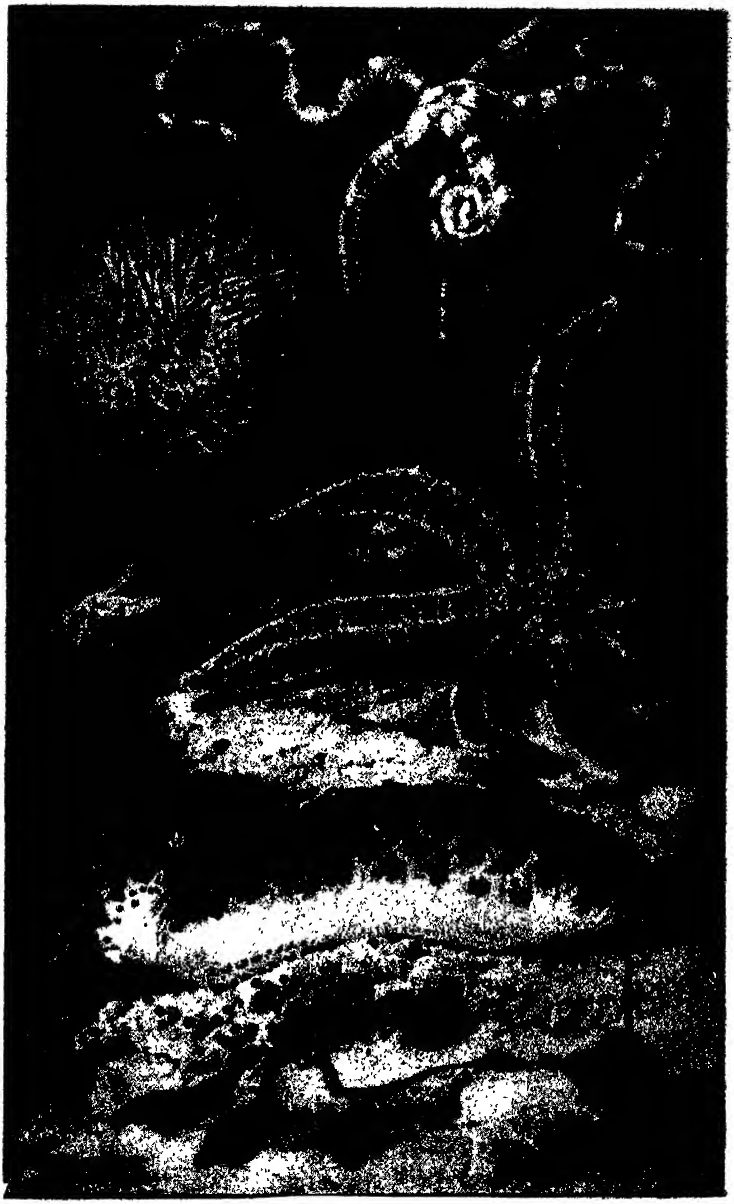
These conform in character to the described type in many at least of the particulars. They are found in all seas, and the majority are inhabitants of shallow water, though some, including the largest species, are found at considerable depths. There are generally five arms, but this is by no means a universal rule. A common British species, for instance, the Sun-Star (*Solaster papposus*), possesses no less than thirteen. The name has been given on account of its resemblance to the conventional symbol by which the sun is usually represented, *i.e.* a circle with a number of radiating lines.

ECHINODERMS

The animals here included constitute a well-marked group of marine animals, in which the body is typically star-shaped or spheroidal, or less commonly cylindrical. There is a more or less perfect calcareous skeleton developed in the skin, and part of it may consist of fixed or movable spines, hence the name of the group (Gk. *echinos*, a hedgehog; *derma*, skin: *i.e.* hedgehog-skinned). A peculiar system of tubes is present, containing sea-water and communicating with the exterior. In three of the constituent classes (star-fish, sea-urchins, and sea-cucumbers) part of this "water-vascular" system consists of sucker-like *tube-feet*, which are used for executing crawling movements.

Four common British forms are figured as types of the four classes now dominant, *i.e.* Star-fish (*Asteroidea*), Brittle Stars (*Ophiuroidea*), Sea-urchins (*Echinoidea*), and Sea-cucumbers (*Holothuroidea*).

1. Purple-tipped Sea-urchin (*Echinus miliaris*). Body covered by numerous spines attached by ball-and-socket joints to little knobs. ("*Urchin*" is an old name for the hedgehog.)
2. Black Sea-cucumber (*Holothuria nigra*). Leathery skin, in which scattered calcareous plates are embedded.
3. Brittle Star (*Ophiura*) Disc-like body with five flexible limb-like arms.
4. Common Star-fish (*Uraster rubens*). With five arms which are extensions of the central body. (The large specimen figured has more than the usual number of arms.)



ECHINODERMS

1. Sea-urchin. 2. Black Sea-cucumber. 3. Brittle Star. 4 Common Starfish.

Class II.—BRITTLE-STARS (Ophiuroidea)

The members of this class, though to some extent they resemble ordinary star-fishes, and are by some naturalists included with them in a common section of the phylum, differ in a number of important particulars. There are a number of British species, of which one of the commonest (*Amphiura squamata*) is a little creature found on the under sides of stones near low-tide mark (fig. 279). It is at once evident that the five *arms* are sharply marked off from the *central disc*. They are indeed more of the nature of appendages, and are here the organs of locomotion, for which their extreme flexibility eminently fits them. Upon the under side of the disc, as in an ordinary star-fish, is situated the *mouth* in the form of a five-rayed slit. There are no ambulacral grooves, and the under side of each arm is covered by a regular series of flat plates, at the sides of which the *tube-feet* project. They are not, however, used as feet, but serve as organs of touch and respiration. There are no eye-spots on the tips of the arms. Turning to the upper surface, no trace of a madreporite can be seen; it is represented by one of the plates situated interradially on the under side. There is no intestinal opening at all. Each arm is covered by a single series of plates, and a similar series runs along each of its sides. The margins of the arms are spiny, but there are no pedicellariæ.

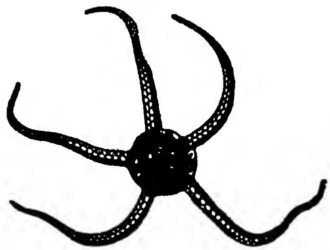


Fig. 279.—Brittle-Star (*Amphiura squamata*), seen from above. Enlarged

There are important differences as to internal structure between a brittle-star and an ordinary star-fish. The *mouth*, for example, is armed by a number of modified plates, and it leads into a spacious *stomach*, which bulges out into ten very short pouches. But there is no intestine and no digestive structures in the arms. Indeed each of these is traversed by a special series of ossicles, which have been called vertebral, because they are jointed together something like the successive vertebræ making up a backbone. Each of them is formed by the fusion of two ossicles, which are equivalent to a pair of the ambulacral ossicles of an ordinary

star-fish. The stomach is not capable of being protruded as in one of the ordinary Stars.

Class III.—SEA-URCHINS (Echinoidea)

Among the animals commonly brought up by the dredge in British seas, and sometimes thrown up on the beach by storms is the Edible Sea-Urchin (*Echinus esculentus*) (fig. 280), which,

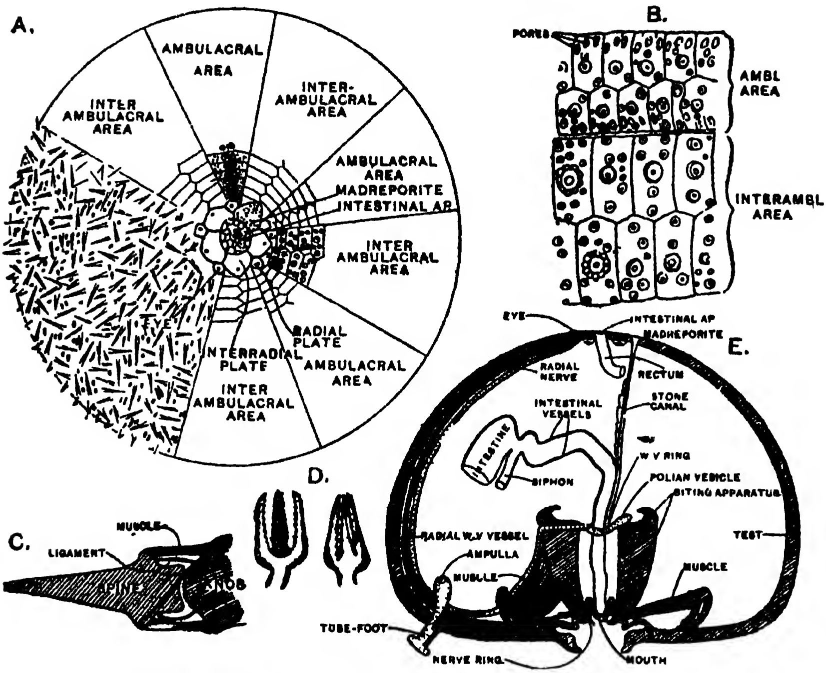


Fig 280 —Edible Sea Urchin (*Echinus esculentus*)

B, C, D, Enlarged to various scales A Diagram of upper surface, with most of spines removed B Plates of small part of an ambulacral and an interambulacral area, with spines removed. Pores for tube feet and knobs for spines are shown C, Diagrammatic section through spine and knob, to show mode of attachment D, Pedicellariæ E, Diagram of side-dissection, most of gut having been removed W V is an abbreviation for "water vascular

though it differs very much in appearance from a star-fish, is really constructed on much the same type. The spheroidal body suggests in appearance a curled-up hedgehog, whence, as previously explained, the name "sea-urchin", the appearance being due to the presence of an enormous number of *spines*, movably jointed to the underlying calcareous plates which, united firmly at their

edges, constitute a firm protective "test". The base of each spine is hollowed out into a cup which fits over a corresponding knob on the test, so that there is a ball-and-socket joint arrangement, and by means of special strands of muscle the spine can be moved in any direction. This is an adaptation to locomotion as well as to protection. Effective *tube-feet* are, however, present, and in a living sea-urchin these may be seen protruding between the spines, and if we compare the animal to a globe with upper and lower poles, their distribution is expressed by saying that they are arranged in five meridional bands.

As in a star-fish, the *mouth* is situated in the centre of the under surface, but in this case there are five pointed structures to be seen projecting from it, these being the tips of hard *jaws* shaped something like the front teeth of a rabbit. The opening of the intestine is placed almost in the middle of the upper surface.

On scraping away the spines, the characters of the *test* may be studied in detail, and it is found to be made up of twenty regularly arranged sets of plates arranged in ten strips, which are broad in the middle but narrow at either end, like the "gores" which make up a balloon, or are sewn together to cover a child's cloth-covered ball. Two meridional rows of plates are united to make up each of these bands. Five of these differ in one important particular from the others which alternate with them, the distinction resting in the presence of a series of *pores* arranged in pairs, and placed near either edge of the band to which they belong, Each pair of these pores belongs to a tube-foot, which is thereby placed in communication with a radial water-vascular vessel, and with an ampulla (see p. 453), both of these being situated within the test. The presence of these pores enables us to distinguish between five *ambulacral areas*, bearing tube-feet, and five intervening *inter-ambulacral areas*. The former correspond to the radii about which the body is symmetrically built, and the others are consequently interradial. It may be useful to institute a comparison with the star-fish, taking for the purpose, not the common form, but the kind (*Goniaster*) shaped like a pentagonal disc. If we suppose the body of such a form to gradually swell so as to become spheroidal, while at the same time the original upper surface gets smaller and smaller, the lower surface (bearing the tube-feet), becoming correspondingly extended, the sea-urchin type will be produced. For the five ambulacral grooves will be converted into the five

ambulacral areas, and the regions between them into the five interambulacral areas.

There yet remain one or two other points to be noticed in the sea-urchin test. The plates at the upper pole, in the neighbourhood of the intestinal aperture, are somewhat specialized, and constitute an *apical disc*, the most important elements in which are ten plates, of which the five smaller ones are situated radially, and therefore correspond with the upper ends of the ambulacral areas. Each of them is called an "ocular", because it bears an eye-spot. The five interradial plates are somewhat larger, and one of them is modified into the *madreporite*, which has the same function as in an ordinary star-fish (see p. 452). Like that animal, too, the sea-urchin possesses those modified jaw-spines to which the name of *pedicellariæ* has been given, but in this case the jaws are three, and not two in number (fig. 281). Some possess poison-glands (fig. 281, right).

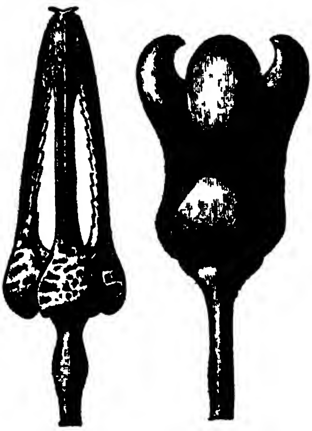


Fig. 281.—Three-jawed Pedicellariæ of Sea-Urchins, greatly enlarged

The *digestive organs* consist of gullet and intestine, the latter taking a spiral course, while the former traverses a complicated chewing apparatus fancifully called "Aristotle's lantern", and made up of the five jaws, together with many other hard parts. By means of special muscles the jaws can alternately be brought together and separated. As in the other groups of Echinoderms so far dealt with, there is a *blood system* of rather obscure nature, and the rest of the circulatory organs consist of a particularly spacious body-cavity in which the various internal organs are placed. *Breathing* is effected by the tube-feet, and also by ten branching *gills* placed in the neighbourhood of the mouth, and resembling the structures which project between the interstices of the skeleton in a star-fish (p. 453). This function is also possibly assisted by a narrow tube (siphon) running parallel to the gut and opening into it at either end. The *water-vascular system* is arranged on the same general plan as in a star-fish (p. 453), consisting of a ring round the gullet connected with the madreporite by a stone-canal,

and giving origin to five radial vessels of which the tube-feet are branches, these vessels, however, running within the test. The *nervous system*, too, is of the same general kind, but there are two nervous net-works, one outside the test and the other within it.

Sea-Urchins are grouped in two divisions: I. *Regular forms*, of which the just-described species is typical, and II. *Irregular forms*, in which there is a strongly-marked bilateral symmetry, and the body is often flattened, while the upper parts of the ambulacra are broadened out so as to collectively make up a flower-shaped figure, the tube-feet of which are definitely specialized into *gills*. These irregular forms again are divided into Shield-Urchins and Heart-Urchins.

Shield-Urchins are sometimes very much flattened, as the name implies, and though the mouth has the normal position, the aperture of the intestine is shifted back into an interradial position.

Heart-Urchins are distinguished by the shape under which the heart is conventionally represented, the notch of the heart being in front. The opening of the intestine is displaced to the edge of the disc, and the mouth, instead of being central, is shifted forwards. The Heart-Urchins are devoid of the special chewing apparatus known as "Aristotle's lantern". A common British species is the Purple Heart-Urchin (*Spatangus purpureus*).

Class IV.—SEA-LILIES AND FEATHER-STARS (Crinoidea)

This is a decadent group, once of great luxuriance, but of which the most typical modern representatives are rare, and confined to the very deep sea. Taking such a typical Sea-Lily, for example, as *Pentacrinus* (fig. 282), it may roughly be compared to a star-fish with branching arms placed on the top of a long stalk, and having its mouth surface turned upwards. A certain vague sort of resemblance to a flower upon its stem has suggested the name.

Examining Pentacrinus more closely, there will be seen a relatively small central disc, or *cup*, as it is usually termed, from which five arms project. These are of the nature of appendages, and begin almost at once to branch in a forking manner. Each branch bears a double series of short filaments termed *pinnules*, the name having reference to the arrangement seen in some plants,

e.g. in many ferns, where a central axis supports a row of leaflets on each side in a feather-like way. The *mouth* is in the centre of the upturned disc, and from it radiate five *ambulacral grooves*, corresponding to the similarly-named structures in a star-fish (p. 451). As the arms branch, so do these grooves, and their smallest subdivisions run along the pinnules. Projecting from each side of an ambulacral groove and its branches are a series of delicate pointed structures representing the tube-feet of a star-fish, but here no longer having anything to do with locomotion. The intestine

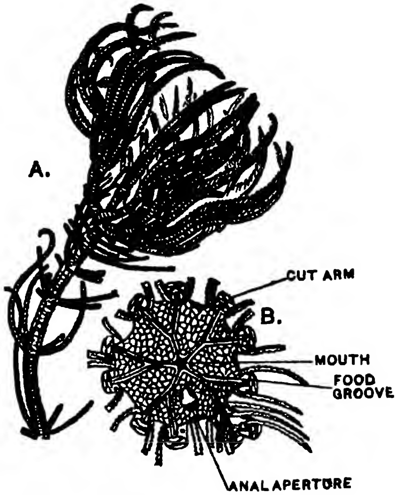


Fig. 282.—Sea-Lily (*Pentacrinus*)
A, Calyx and part of stalk (reduced) B, Upper side of calyx, with arms cut off.

opens near the mouth upon a projection situated in one of the interradial spaces. The under side of the cup is supported by regularly-arranged circlets of calcareous plates, some of which are comparable, it would appear, with the apical disc of a sea-urchin. There is, however, no madreporite. The under side of each arm, arm-branch, and pinnule is also supported by a series of hard parts, jointed together, however, so as to permit of a certain amount of movement. The stalk upon which the animal is supported is five-sided, and it is supported by a series of calcareous pieces, in the form of prisms

Fig. 283.—Feather Star (*Comatula*), climbing

joined end to end. At regular intervals the stalk bears circlets of jointed filaments (*cirri*) which also are strengthened by a deposit of lime.

The *internal structure* is very complex, and it need only be said that the gut does not extend into the arms, and that apart from it the chief organs have the radial arrangement described for other types.

Although Sea-Lilies are distinctly scarce animals, the same can scarcely be said for the Feather-Stars, of which one kind (*Antedon* or *Comatula rosacea*) (fig. 283) is not uncommon in British seas. Its *life-history* is one of peculiar interest, for the eggs develop into a stalked *larva* which is found attached to sea-weed, and looks like a minute Sea-Lily (fig. 284). Later on, the stalk disappears and the animal takes to a free life, though it is possessed throughout its existence of a circlet of cirri, corresponding to the top circlet of those structures in a stalked form, and used to anchor the creature, and also in climbing. The life-history is interesting, chiefly because it is one of the best-known examples of a case where the development of the individual is a compressed presentment of the genealogy of the species. If the Feather-Star were the only known Crinoid there would be a strong presumption that its remote ancestors were stalked, and this conclusion is fully borne out by a study of recent and fossil forms.

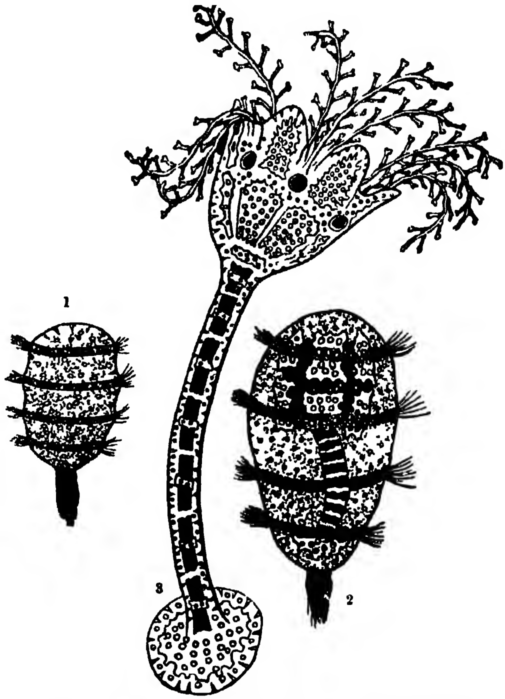


Fig. 284. Stages in development of Feather Star (*Comatula*), much enlarged. 3 is the stalked or pentacrinus stage

CLASS V.—SEA-CUCUMBERS (HOLOTHUROIDEA)

These are for the most part leathery elongated forms, some of which look uncommonly like cucumbers, a similarity which has suggested the name of the group. They are regarded by some authorities as representing most nearly of living animals the ancestral stock from which all Echinoderms must be supposed to have taken origin. This, however, is extremely doubtful; but as unfortunately the class, unlike the other ones included in the phylum, is but poorly provided with hard parts, fossil remains are infrequent, and throw but little light upon the question.

In a typical Holothurian (such as the genus *Cucumaria*) (fig. 285) the elongated body is somewhat angular, and the two openings of the digestive organs are at opposite ends of the body, the *mouth* being surrounded by a circlet of ten branching *tentacles*, which can be retracted. The *ambulacral areas* are marked by five double rows of *tube-feet* protruding along the side of the body. No trace of a madreporite can be discerned. The body-wall consists of skin and underlying muscles, the latter being as well developed here as they are scanty in those forms which have a well-developed exoskeleton. The *hard parts* of a Holothurian are comparatively insignificant, the most important of them making up a calcareous ring round the gullet; and there are, besides, minute calcareous spicules scattered through the skin.

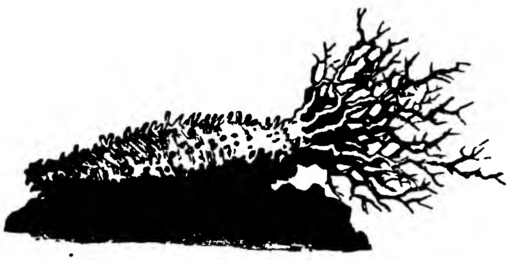


Fig 285.—A Sea Cucumber (*Cucumaria*), reduced

The *mouth*, as already stated, is placed in the middle of the crown of *tentacles*, and these are arranged in five pairs, one for each ambulacral area. One pair is smaller than the rest, and is used in shovelling food into the mouth. They correspond to the under surface of the body, which in some other members of the group is very sharply defined, though here the radial symmetry is not much interfered with. The mouth leads into a mouth-cavity, which opens into a gullet, and this again into a looped

intestine, which dilates near its termination into a section which is known as the *cloaca*, though it can scarcely be said to correspond to the similarly-named cavity found in many of the vertebrate animals (see pp. 69, 146, 200, 240, 261).

The *circulatory organs* consist, as in a star-fish or sea-urchin, of a blood system and a lymph system. The former is chiefly made up of a ring round the beginning of the gut, of five radial vessels, and of branches to the digestive and some of the other internal organs. The lymph system consists of the spacious body-cavity filled with fluid, in which float both colourless and red corpuscles, reminding us of the blood of a typical vertebrate (see p. 38).

Breathing is no doubt partly effected, as in other cases, by the tentacles and tube-feet, but there are also other structures which probably have to do with the same function, in the form of two large branching *respiratory trees* that open into the cloaca. The branches of these organs are beset with innumerable minute ciliated funnels, by which the body-cavity is placed in communication with the exterior. It is extremely likely that these trees also have to do with getting rid of the nitrogenous waste of the body, and if so, they are *excretory* as well as respiratory organs.

The *water-vascular system* is constructed on the same plan as in a star-fish. There is a ring round the beginning of the gut from which a radial vessel runs along each ambulacrum to give off the double row of tube-feet. Branches of these vessels supply the tentacles, which are to be regarded as much-modified tube-feet, and there is a stone-canal with a madreporite which, instead of opening to the exterior, hangs down into the body-cavity. In a very young Holothurian, the stone-canal opens directly to the exterior, as in a star-fish or sea-urchin, but this connection is lost in the typical forms, though there are some deep-sea species in which it persists throughout life.

The *nervous system* is of the type already described for other subdivisions of the class (p. 454). *Sense Organs* are chiefly represented by the tentacles and tube-feet, which no doubt have to do with the sense of touch.

Within the limits of the class there are numerous variations in many respects. Certain deep sea forms present a well-marked bilateral symmetry, and the body is produced into pairs of projecting processes. In such forms, a well-marked flattened lower

surface upon which the animal creeps presents a sharp contrast with the curved upper surface. This is also the case with some of the species inhabiting much shallower water, and in these bilateral forms, three of the ambulacra are turned downwards, and bear tube-feet used in locomotion, while the other two face upwards, and their tube-feet are modified into pointed structures useful only as organs of breathing and touch. The tentacles also present a considerable variety in size and shape. Some common forms have the tube-feet irregularly scattered over the body instead of being arranged in rows, while in yet others the tube-feet, and even the radial branches of the water-vascular system, are absent altogether. This is the case, for example, in the genus *Synapta*, species of which are found in British seas. Here the translucent body is worm-like, and the small tentacles are feather-shaped, a further character of interest being found in the shape of the calcareous plates embedded in the skin, which are in the form of anchors with associated oval perforated plates (anchor plates). It also possesses ten minute ***auditory sacs*** in close connection with the nerve-ring.

CHAPTER X

STRUCTURE AND CLASSIFICATION OF ZOOPHYTES (CŒLENTERATA), SPONGES (PORIFERA), AND ANIMALCULES (PROTOZOA)

ZOOPHYTES (CŒLENTERATA)

The old expression "zoophyte" was applied to branching colonies of organisms regarding the animal nature of which doubt existed, and which were looked upon as being intermediate between animals and plants. Here were included the forms already briefly dealt with under the heading of Polyzoa (p. 436), but these are of much higher structure than the bulk of zoophytes, which may conveniently be grouped together under the phylum now to be considered. This embraces the Corals, Jelly-Fish, Sea-Anemones, and other creatures less familiar to the ordinary observer. As a simple and easily obtained type, it is customary to take the *Fresh-water Polype* (*Hydra*) (fig. 286), which is often found attached to pond-weeds, or sticking to the glass of a fresh-water aquarium. By leaving such an aquarium in a brightly-lit window for some time, one may often secure a supply of these animals, which collect on the side next the light. As they are not more than about $\frac{1}{4}$ of an inch long, the naked eye alone is not sufficient for their proper examination. Much can be made out with a simple lens, but a compound microscope is necessary to determine details. This is one of the numerous cases where important results are to be obtained by means of cutting thin slices with a razor, an operation which requires that the animal

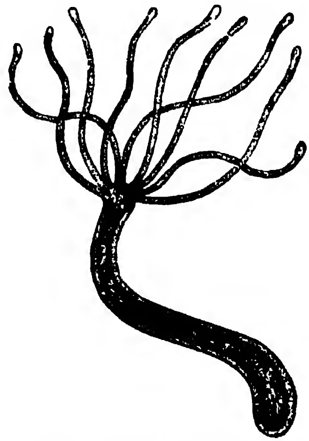


Fig. 286.—Green Hydra (*Hydra viridis*), enlarged

should be killed, stained, and imbedded in paraffin wax or some similar substance. Extremely delicate slices of known thickness can be cut by means of the instrument known as a *microtome*, in which a sharp razor is mechanically drawn across the imbedded specimen, this being held firmly by a suitable device. The slices, when prepared, have to be cleared from paraffin and mounted on a glass slide, in some transparent medium, such as glycerine or Canada balsam.

Specimens of Hydra are brown (*e.g. Hydra fusca*) or green (*Hydra viridis*) (fig. 286) according to the species, but in any case the form and structure are much the same. The colour of the green kind is particularly interesting, since it is due to the presence of a pigment (chlorophyll) which is characteristic of ordinary plants, and, as we shall see later, plays a leading part in their nutrition. The body of a fully-extended individual is a hollow cylinder closed at one end, the *foot*, by which attachment to a firm object is effected, while it is narrowed and open at the other, the aperture being the *mouth*. A circlet of long slender *tentacles* is situated quite close to the mouth, just where the body begins to narrow. The large internal *digestive cavity* has no other opening to the exterior. We find here a perfect example of the star-like or *radial symmetry* which is exemplified in a less complete manner by a star-fish or regular sea-urchin, and there is absolutely no trace of the bilateral symmetry so characteristic of higher forms (see p. 21). In other words, there is no distinction between front and back ends, right and left sides, or dorsal and ventral surfaces.

If a fully-extended Hydra be touched or shaken it will at once become retracted, its body shortening into a little rounded lump, while the tentacles become minute knobs. Such an arrangement is obviously of a protective character. When in an extended position the animal is on the look-out for prey, if such an expression may be used in the absence of visual organs. Its food consists of small aquatic animals such as Water-Fleas (see p. 422), which are much higher in the scale, and would at first sight appear to have every chance of escaping capture. This, however, is not the case, for if one of these active creatures happens to come into contact with one of the tentacles of the Hydra it stops dead as if paralysed, and is then by the help of the other tentacles drawn down to the dilatable mouth and passes out of view into

the digestive cavity. The sudden arrest of activity on the part of the unfortunate water-flea is brought about by means of minute "thread-cells" or "nettling-cells", which, as will be explained elsewhere, are poisoned weapons of considerable virulence. Numerous groups or "batteries" of these are present upon the tentacles, on which they confer a roughened appearance, and they are also present, though less abundantly, upon other parts of the body. *Nettling-cells* are very characteristic of the Cœlenterates, a fact which has been painfully brought home to many bathers in the case of some of the larger jelly-fish, while even the innocent-looking sea-anemones have been known to seriously inconvenience persons who happened to touch them. Even, therefore, if Hydra, like many of its brethren, were condemned to remain fixed in the same spot it would not necessarily be starved, but, as already hinted, it possesses considerable powers of *locomotion*. It can, for example, slowly shuffle along upon the attached end of the body, and can also execute looping movements by alternately attaching the two ends of its body to the surface of a stone or water-weed, reminding one of what happens in the case of a leech (p. 432) or a looper caterpillar (p. 364). Specimens may also be found floating freely in the water, mouth downwards, with the foot close to the surface and held in place by what is known as surface tension.

Structure of the Body (fig. 287).—Most of the external characters of Hydra have now been dealt with, and it remains to consider the minute structure of the body as determined by means of the microscope. Much can be learnt by examination of a thin cross-section, which may instructively be compared with a similar section through the body of an earth-worm. There is a central space corresponding to the digestive cavity, and outside this the body-wall, which is clearly made up of an outer layer and a much thicker inner layer, the two being separated by a thin membrane (supporting lamella). These two layers are respectively known as the *ectoderm* (Gk. *ektos*, outside; *derma*, a skin) and *endoderm* (Gk. *endon*, within; *derma*, a skin), and a double body-wall made up in this way is eminently characteristic of Cœlenterates and Sponges, especially in embryonic stages, on which account these two phyla are often grouped together as the "*Diploblastica*" (Gk. *diplous*, double; *blastos*, germ or bud). Turning now to the section of earth-worm, we see in the middle

a space corresponding to the digestive cavity or gut which, however, is not bounded directly by the wall of the body but by a wall of its own separated by a considerable space, the *body-cavity*, from the body wall. Hydra is absolutely devoid of a body-cavity in this sense. If we attempt a comparison between the two animals, the epidermis of the worm may be looked upon as *ectoderm* and the innermost layer of the wall of the gut would appear to be equivalent to *endoderm.* But the greater part of body-wall and gut-wall in the worm, together making up what is called the middle layer or *mesoderm*, has no distinct representative in Hydra, unless, perhaps, it is represented in an inadequate manner by the thin membrane between ectoderm and endoderm. The presence of a distinct third layer coming between ectoderm and endoderm is characteristic of all the phyla above the Zoophytes, and this comes out very clearly and simply in embryo stages. Hence all these phyla are collectively grouped together as *Triploblastica*, *i.e.* three-layered animals, as contrasted with the two-layered forms or Diploblastica. The body-cavity is simply a split in the mesoderm, dividing it into an outer sheet lining the ectoderm and an inner sheet investing the endoderm.

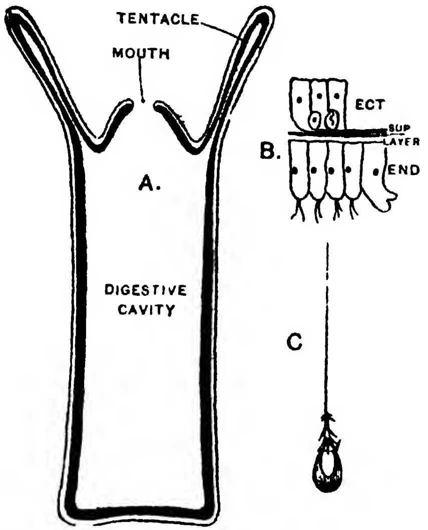


FIG. 287.—Diagrams enlarged to various scales, illustrating the structure of Hydra.

A, Longitudinal section: ectoderm left white, endoderm represented in black. B, Small part of longitudinal section through body wall (the black dots are nuclei): ECT, three large cells and two packing cells are seen; SUP LAYER, supporting layer or lamella; END, endoderm, showing four cells with flagella, and one with pseudopodia. C, A nettling cell, with thread protruded: note barbs at the base of this, and the trigger hair on the right side; the protoplasm investing cell is shaded, and the nucleus represented in black.

Allusion has already been made to the fact that the body of a higher animal is made up of a number of different sorts of material having specific purposes and known as *tissues*, which are in effect the building materials from which the various organs are constructed. They are as follows:—1. *Epithelium*, consisting of

membranes which line internal cavities and cover the external surface, having in the latter case the name of epidermis; 2. *Supporting tissues*, such as bone, gristle (cartilage), and connective tissue which makes up tendons and ligaments, while it is also found as a sort of supporting framework in almost all parts of the body; 3. *Muscle*, constituting the flesh or meat, and also entering largely into the construction of the walls of various internal organs, such as heart and stomach; 4. *Nervous tissue*, constituting the essential part of the nervous system; and 5. *Blood* and *Lymph*, which must be looked upon as liquid tissues, serving as media of exchange. In a higher animal these various tissues are highly specialized so as to fit them for particular kinds of work; *e.g.*, muscle has as its province the bringing about of active movements. Indeed it may be said that animals are "high" or "low" in proportion as the division of physiological work is completely or incompletely carried out. In a high animal there is great complexity of structure associated with this perfect division of function, while exactly the reverse is true for a low animal. And in degenerate forms, such as the Ascidians (p. 297), animals derived from relatively complex ancestors have become simplified so as to suit them for simpler conditions of life. The loss of digestive organs by tape-worms (p. 441) is a further example of the principle.

Careful examination of any one kind of tissue shows that it is entirely or largely composed of structural units known as *cells*, comparable to the bricks and stones, &c., which make up the building materials of a house, if we pursue a comparison which has elsewhere been made use of. It is these cells that consist of the actual living substance, *protoplasm*, with which vital actions are associated. Each cell contains a particle of specially modified protoplasm known as the *nucleus*, which appears to be a regulative centre. These cells differ largely in shape according to the nature of the tissue. A simple case is that of lymph (p. 41), which consists of a clear fluid (plasma) in which are suspended innumerable irregular lymph corpuscles, which in this instance are the constituent cells. *Epithelium* (fig. 288) again consists of one or more layers of cells closely packed together and possessing various shapes in different cases. There is, for example, simple *scaly epithelium*, made up of flattened cells united by their edges and only one cell thick; this is comparable to a tessellated pave-

ment, each separate bit corresponding to a cell. The lining of heart and blood-vessels is of this nature. *Stratified scaly epithelium* resembles the preceding, but is several cells thick. Examples are to be found in the lining of the human mouth, and the epidermis of Frog. *Simple columnar epithelium* consists of prismatic cells packed together in a single layer, and is very characteristic of stomach and intestines. Other examples will be noted elsewhere. In many cases the surface cells of epithelium are provided

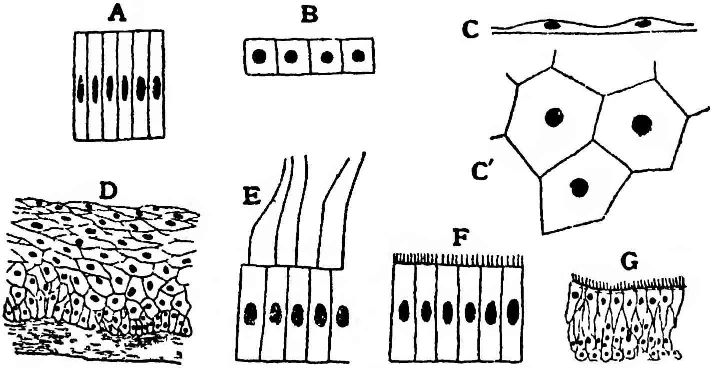


Fig. 288. Different kinds of Epithelium, enlarged to various scales. All except C′ are in vertical section. Nuclei represented in black.

A, Simple columnar; B, simple glandular; C, simple scaly; C′, simple scaly, surface view; D, stratified scaly; E, simple columnar, with flagella; F, simple columnar, with cilia; G, stratified, with cilia.

with numerous slender threads of protoplasm, cilia, which by their united action can set up currents. An individual *cilium* possesses the power of alternately bending and straightening itself. Various examples have already been given of the presence of such structures (pp. 49, 428, 445).

The *ectoderm* and *endoderm* of Hydra are to be regarded as tissues, but do not exhibit the high degree of specialization found in the phyla so far dealt with. They are more of the nature of epithelium than anything else, and this form of tissue is justly regarded as a comparatively primitive one. Beginning with the *ectoderm* (fig. 287), we find that the largest elements contained in this are what may be termed *tailed-cells*, since each of them is drawn out at its inner end into a fibre which appears to be of muscular nature. These tails all take a longitudinal direction, and collectively constitute a muscular layer by means of which the body can be shortened, supposing the fibres to contract or shorten

simultaneously. Filling up the spaces between these large cells are much smaller *packing-cells* with indistinct outlines, some of which become transformed into the *nettling-cells* already noticed, and force their way to the surface. Deep down in the ectoderm are also to be found scattered *nerve-cells* of star-shaped outline, collectively representing an extremely primitive form of nervous system.

The *endoderm cells* of Hydra are much larger than those of the ectoderm, and are provided with muscular tails running in this case transversely, so that collectively they make up a circular muscle layer, by the contraction of which the body can be extended. These cells also have digestive functions, and their free ends, which are directed towards the digestive cavity, can be protruded into lobes by which food particles are bodily engulfed, or, to speak more technically, ingested. Many of the cells are also provided with groups of protoplasmic filaments, which execute lashing movements by means of which the contents of the digestive cavity are kept circulating. These are called flagella (L. *flagellum*, a whip), and though they are in some respects allied to cilia, differ from them in the relative complexity of their movements, their larger size, and the fact that but a small number of them are to be found on the same cell. In the green Hydra, the endoderm cells contain numerous spheres in which the characteristic pigment is contained, while in other species similar spheres are present, differing, however, in the nature of the colouring matter.

From what has been said concerning Hydra it will be seen that in this animal there is but little specialization or division of the work of the body. As to *digestive organs*, the animal is little more than an animated stomach, food being procured by the action of the tentacles, and digested by the endoderm. *Circulatory organs* are entirely absent, and, indeed, they are not necessary, for the digested food can easily diffuse to all parts of the body. Waste products are similarly easily got rid of, and there are therefore no special organs of *respiration* or *excretion*. Both *nervous system* and *sense organs* are in a very undifferentiated condition, the latter being chiefly represented by sensitive "trigger hairs", with one of which each thread-cell is provided.

Development (fig. 289).—New Hydræ are produced either by a process of *budding* or from eggs. In the former case, a little knob

is seen to make its appearance on the body-wall, and, becoming gradually larger and larger, is shaped by degrees into a fresh individual, which ultimately becomes detached. This process goes on very vigorously in summer, and a Hydra may often be found bearing several mature buds, which, in their turn, are giving rise to a third generation. A temporary form of branching tree-like form is thus produced. Late in the summer, when external conditions as regards temperature and food become unfavourable, one or more rounded projections make their appearance near the foot, each of them containing an *egg*. After developing to a certain

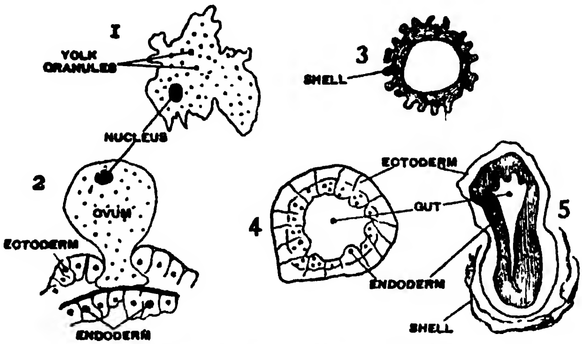


Fig. 289 —Development of Hydra, greatly magnified

1, Ovum. 2, Ovum, projecting from body-wall of parent 3, Section through young embryo, to show protective egg-shell 4, Cross-section of older stage. 5, Longitudinal section through embryo after rupture of egg shell.

extent, the egg surrounds itself with a firm horny coating, serving as an efficient protection, and, invested in this, falls from the parent animal into the mud at the bottom of the pond or stream, where, in a dormant state, it is able to survive the winter, which is not usually the case with the Hydra itself. The development is completed in the following spring, when the egg-shell splits and the young animal makes its way out. In many groups of the animal kingdom, it is a common phenomenon for "winter eggs" of this kind to be produced, and the extinction of the species during the cold season is thereby prevented. A comparison may well be drawn with the seeds of higher plants, in which dormant embryos are contained that are able to resume growth with the advent of warmer weather.

An interesting property possessed by Hydra is its power of regenerating parts which have been injured or removed. To such

an extent is this carried, that if an individual is cut into several pieces, each of them becomes a fresh Hydra. Powers of this kind are common among lower animals, and, as might be expected, are greatest where the body is but little specialized, as in the case now under consideration. Another case was mentioned when dealing with the Star-Fish (p. 454). The absence of specialization in Hydra is not so great, however, as supposed by the older zoologists, who imagined that the animal was so little discomposed when turned inside out that it lived on with the functions of the layers reversed.

Zoophytes are conveniently divided into the following three classes:—1. Sea-Flowers (Anthozoa or Actinozoa); 2. Hydroids (Hydrozoa); and 3. Comb Jelly-Fish (Ctenophora),

Class I.—SEA-FLOWERS (Anthozoa or Actinozoa)

The brilliantly-coloured Sea-Anemones, Corals, Sea-Pens, and the like, which are grouped together in this class, justify its name (Gk. *anthos*, a flower; *zōŏn*, an animal), for, when expanded, they look not unlike chrysanthemums or double dahlias, to the individual florets of which the numerous tentacles bear a certain resemblance. Many of them are colonial, while others live singly, and of these we may take the common *Beadlet* (*Actinia mesembryanthemum*) as an example (compare fig. 290). It is abundant on rocks between tide-marks all round our coasts, looking, when expanded, like a scarlet flower, but shrinking to a rounded jelly-like mass when contracted. In the former condition, it may be compared to a short broad Hydra, but the mouth is in the centre of a wide disc, and is surrounded by several rows of comparatively short pointed tentacles. There are, however, important differences in structure. The *mouth* leads, not into a widely-continuous digestive cavity, but into a tubular *gullet*, which hangs down within the body, and ends abruptly below. This may be roughly represented by taking a piece of wide india-rubber tubing, and tucking in one end of it. The space between the lower end of the gullet and the base is called the *stomach*, and performs the function of a digestive organ. But this is not all, for running across in a radiating way from the body-wall to or towards the gullet are a large number of fleshy partitions, which divide the space external to gullet and stomach into a number of compartments. These partitions, or *mesenteries*, are, however, perforated above, so as to

put adjoining compartments into communication. The stomach, which is bounded by the thickened free edges of the septa, is of necessity continuous with the various compartments, except when digestion is going on, at which time the edges of the septa are brought close together, a digestive juice being poured out from them upon the food. These points will be made clear by examination of the accompanying diagram. It may further be noted that the sides of the gullet are furrowed by two grooves placed opposite to each, and this organ can be collapsed in such a way as to convert these grooves into narrow tubes, these being lined by long cilia, which work in such a way that a current of water runs inwards in one tube, and outwards in the other.

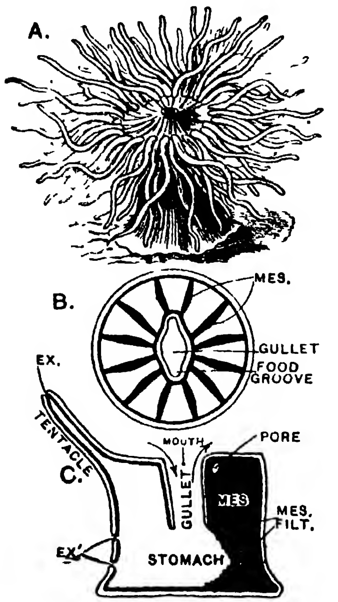


Fig. 200. Sea Anemone.

A, External view of a Sea Anemone (*Anemonia*). B, Diagrammatic cross section. MES., mesenteries; only one of the two food-grooves is lettered. C, Diagrammatic longitudinal section, showing a mesentery (MES.), with mesenteric filaments (MES. FILT.) on the right, and one of the spaces between two mesenteries on the left. EX., EX'., excretory pores. The arrows indicate the course of currents into and out of the gullet along the food grooves.

The *minute structure* corresponds in many ways to that of Hydra, there being ectoderm, endoderm, and a supporting lamella between them. Nettling-cells are abundantly present, but are more complex in pattern than those possessed by Hydra. There is further a greater amount of specialization, as seen especially in the muscular and nervous systems.

The Anthozoa include two orders:—1. Six-rayed Sea-Flowers (Hexactinia); and 2. Eight-rayed Sea-Flowers (Octactinia).

Order 1.—Six-rayed Sea-Flowers (Hexactinia)

These are distinguished by the fact that the tentacles are simple, while they and the mesenteries are usually arranged in multiples of six, and though this is often difficult to easily make out in the adult, it is clearly shown during the development. The Sea-Anemone just described is a good type of the order. Among

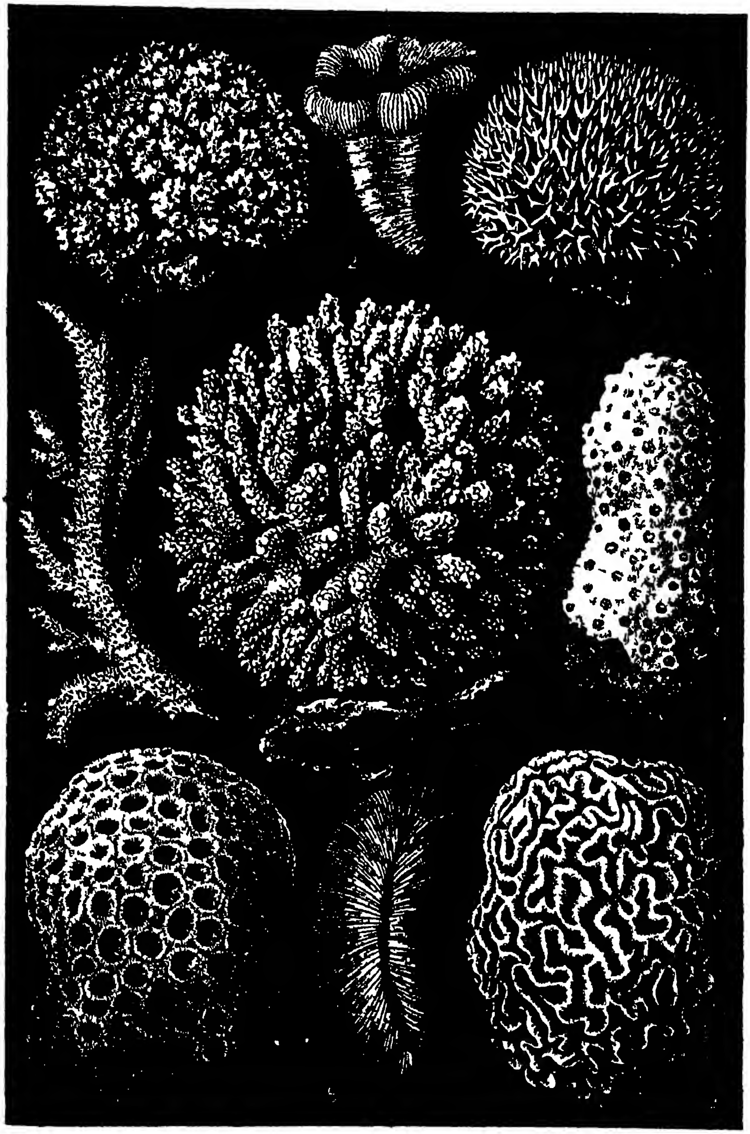


Fig 291 —Skeletons of Arabian Corals, all reduced

1, Tuft-Coral (*Pocillopora favosa*), 2, Clove Coral *Trachyphyllia Geoffroyi*) 3 Antler Coral (*Seriatopora subulata*) 4, Madrepore-Coral (*Madrepora laxa*), 5 Shrub-Coral (*Heteropora Hemprichii*) 6, Hedgehog Coral (*Echinopora gemmacea*) 7, Sun Coral (*Heliastræa Forskaliana*) 8, Mushroom Coral (*Fungia scutaria*) 9, Brain Coral (*Cœlaria labyrinthiformis*)

other British anemones may be mentioned: *Tealia crassicornis*, a large red form in which the outside of the body is studded with warts, to which fragments of sand or shells may be found adhering; and the brownish or greenish Opelet (*Anthea cereus*), which can only partially draw in its tentacles.

The majority of forms known as "corals" (fig. 291) are also members of the six-rayed order, and they include both simple and colonial species. Of the former may be mentioned a British species (*Caryophyllia Smithii*) found in the English Channel. In structure it is comparable to a sea-anemone, but a hard calcareous skeleton has been secreted by the ectoderm in the basal part of the animal. When the soft parts are removed this is seen to consist of a conical cup, from which calcareous plates project inward. A simple coral attaining a much larger size is the familiar Mushroom-Coral (*Fungia*), the flattened cup of which has some resemblance to the top of a mushroom, the gills being represented by the calcareous partitions or septa. Most corals, however, form colonies by budding (gemmation) or splitting (fission), and it is these which chiefly build up the coral-reefs so characteristic of the warmer parts of the ocean where the water is free from sand or mud. All sorts of different shapes may be assumed by the colonies, according to the species, some being encrusting or massive, while others branch in a tree-like way (fig. 291). The individual polypes may be separated by a larger or smaller interspace, so that their separate cups can be clearly made out, either imbedded in or else projecting from a *common skeleton* secreted by the common or colonial body (cœnosarc) which unites the different members together. In other cases the polypes are closely packed together, and it even happens in some cases that there is no proper division between them, it being only possible to determine the number of individuals by counting the mouths which are present.

Order 2.—Eight-rayed Sea-Flowers (Octactinia)

Although these forms agree in general plan of structure with corals and sea-anemones they also present striking differences, among which the most obvious are the possession of not more than eight feather-shaped tentacles and the same number of mesenteries. Nearly all the included species are colonial.

One of the commonest British members of the group is the organism to which the unpleasant name of *Dead-Man's Fingers* (*Alcyonium digitatum*) is applied, a name justified to some extent by the thick branches of the colony that look something like the swollen fingers of a clumsy hand (fig. 292). In a specimen cast up on the beach the individual polypes will have been drawn back into the fleshy substance of the colony, their position being indicated only by small depressions situated at a little distance from one another. Quite another appearance is presented by a living specimen with all the polypes protruded, these having a distinctly flower-like appearance, with eight feathery tentacles suggesting petals. As in an anemone, the mouth leads into a gullet, provided in this case, however (as also in some of the anemones), with but one ciliated groove, and united to the body-wall by only eight septa. The digestive cavities of the polypes are continuous with canals which traverse the common flesh. At first there appears to be no skeleton; but microscopic examination reveals the presence of numerous *calcareous spicules* of characteristic shape, scattered through the comparatively thick supporting layer which comes between the ectoderm and endoderm (see p. 474). There is reason to believe, however, that the spicules have been formed by the activity of ectodermic cells which have become detached from their own layer.

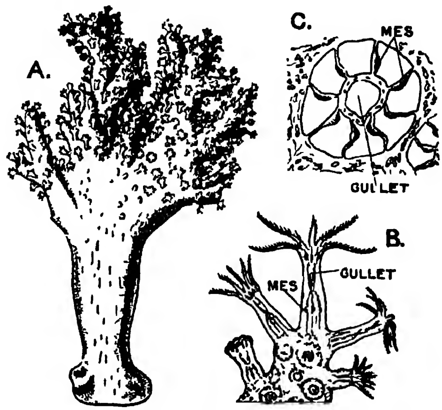


Fig 292 – Dead Man's Fingers (*Alcyonium*)

A, A colony, reduced B, Tip of a branch, magnified, showing polypes in different stages of expansion and retraction, MES, a mesentery C, Cross section through body of a polype, magnified, MES, mesenteries 8 in all are present note the single food groove in lower side of gullet

Another familiar example of the group is the *Organ-pipe Coral* (*Tubipora musica*), in a dried specimen of which may be seen numerous red tubes connected together by "platforms" of similar material at different levels. From these platforms new individuals grow up, and so the coral increases in breadth as it gets older. As in colonial corals generally the individuals are

limited to the surface-layer, while the deeper part of the mass is cut off by partitions and merely consists of dead material. In a living specimen of Tubipora the upper end of each tube is occupied by a polype of similar character to those found in Alcyonium, and adjacent members of the colony are connected by living matter which extends along the uppermost platforms. Microscopic examination of the skeleton shows that it is formed by the intimate union of innumerable minute spicules comparable in nature though not in shape to those of Dead-Man's Fingers.

Other examples are *Red Coral* (*Corallium rubrum*) (fig. 2), where there is a compact branching skeleton (composed of united spicules) covered by the common flesh (cœnosarc) of the colony from which the polypes project at intervals; *Sea-Pens* (*Pennatula*, &c.), where the colony is feather-shaped with a series of individuals on each side, while the axis is supported by a firm rod; and the *Sea-Mats* (*Gorgonia*, &c.), where the flat upright colony is variously branched and supported by a horny skeleton, which is covered by common flesh with polypes much as in the Red Coral.

Class II.—HYDROIDS (Hydrozoa)

The Fresh-water Polype, Hydra, has already been described as a simple type of this class (pp. 465 471), which is predominatingly marine. The apparent simplicity of Hydra, it should be noted, is in all probability the result of reduction, and a much better idea of the group is to be obtained by briefly considering one of those marine forms to which at different stages of the life-history the terms "hydroid zoophyte" and "medusa" are applied. The horny skeletons of zoophytes of this sort are cast up on the shore in abundance by storms, and some may be found growing near low-tide mark in rock-pools. They are often confused with sea-weeds in amateur collections, in which their branching skeletons are frequently to be found. A very common British genus is *Obelia* (fig. 293), for which there is no popular name. It will be remembered that in dealing with Hydra it was pointed out (p. 472) that during summer, when that animal is actively budding, two or three generations of individuals may be temporarily connected together. If these buds were to remain united, and the budding process were carried

further, a permanent branching colony would be the result. Obelia is a colony of this kind, and for its support some sort of skeleton is necessary, as is the case in the corals already described. Here, however, it is in the form of a horny investment, which covers the common body (cœnosarc) and expands at the tip of each branch into a little cup in which is lodged a hydra-like polype. There is, however, a further arrangement in the form of much larger cups (gonangia) within which are produced groups of special buds, the function of which is to produce eggs. When these buds are mature they are liberated in the form of small *jelly-fish* or *medusæ*, which lead an independent life for some time and possess active powers of movement. The jelly-like consistence in cases of the kind is due to the excessive development of the lamella between ectoderm and endoderm, which becomes thick and gelatinous, while cells from the two layers in question make their way into it. The little medusa may be compared to an umbrella with a very short handle (manubrium), and around its margin is a fringe of tentacles, eight of which have minute auditory vesicles at their bases, one to each. The *mouth* is situated at the end of the handle, and leads into a *stomach*, from which four tubes radiate to the edge of the umbrella, where they are continuous with a circular ring-canal. It may further be added that a little shelf or *velum* projects inwards from

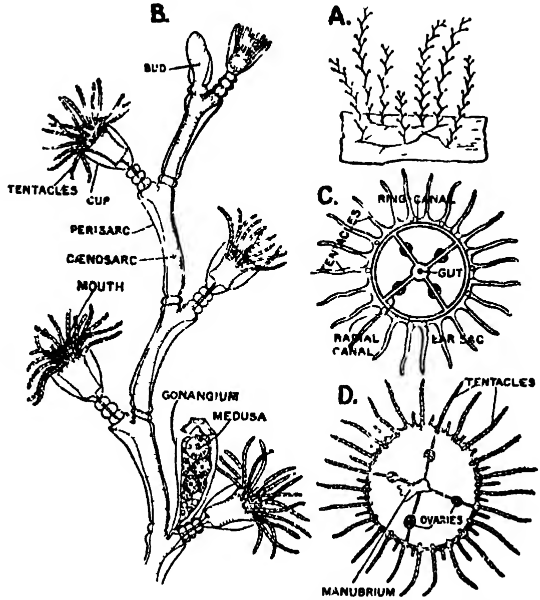


Fig. 291.—Fixed and Free-swimming Stages of a Hydroid Zoophyte (*Obelia*). A, Natural size. B–D, enlarged.

A, A colony of the fixed hydroid stage attached to a piece of sea-weed. B, End of a branch of same. C, Upper side, and D, under side of the free-swimming stage jelly-fish or medusa.

the margin of the umbrella. The eggs give rise to hydra-like individuals, each of which develops a fresh colony by means of budding.

The Hydrozoa may conveniently be divided into two orders: 1. Budding Hydroids (Hydromedusæ); and 2. Splitting Hydroids (Scyphomedusæ).

Order 1.—Budding Hydroids (Hydromedusæ)

Obelia is a good typical example of the order, but in by no means all cases are egg-producing buds set free as medusæ, and a complete series of examples may be selected which range from that condition down to the state of things found in Hydra, where each egg is produced in a little swelling which has no resemblance whatever to a medusa. The intermediate stages are represented by cases where the egg-producing buds resemble medusæ but remain attached to the colony, and other cases where such buds may be compared to medusæ in which some of the typical features have been, as it were, suppressed.

Obelia is a type of one large division in which the fixed stage is distinguished by the possession of *cups* into which the individuals can be withdrawn, while if free-swimming jelly-fish are produced their sense organs are usually auditory vesicles. Other common British genera are *Sertularia* and *Plumularia*.

In another large group the investing skeleton ends abruptly at the base of each polype and does not expand into a cup, while the medusæ, if liberated as free-swimming individuals, usually possess eye-spots instead of auditory vesicles round the margin of the umbrella. *Tubularia* is a typical British genus, in which the polypes are comparatively large, and free-swimming medusæ are not developed. It is also customary to place Hydra in this group, as well as a very interesting marine genus, *Protohydra*, of somewhat similar character, though it has no tentacles, and is to be regarded as the simplest known member of the Hydrozoa.

Although most corals belong to the Anthozoa, there are a few cases of species belonging to the Hydrozoa which, instead of secreting a horny investment, develop a firm calcareous skeleton, and superficially resemble the true corals, though in reality sharply marked off from them by the structure of the soft parts. Representative genera are *Millepora* and *Stylaster*,

in which there are hydra-like *nutritive individuals*, without well-developed tentacles, and reduced *prehensile individuals* devoid of mouths, and looking like large tentacles richly provided with nettle-cells, and branched in the case of Millepora. Each nutritive polype is surrounded by a number of these modified individuals, the function of which is to secure food. There are also egg-producing members of the colony, comparable in function, though not in form, to the medusa-stage of Obelia.

It will have been gathered from the preceding that there is often a division of physiological work between the different members of a hydrozoan colony, just as in the complex body of a higher animal there is a similar division between the various tissues. This phenomenon is carried to an extreme in the free-swimming marine forms which are grouped together under the name of *Compound Jelly-Fish* (*Siphonophora*) (fig. 294). Each colony comprises individuals of the most various nature, and just as a hydroid zoophyte arises by the budding of a fixed hydra-like individual, so here we must suppose that buds of different kinds have been produced on a modified jelly-fish or medusa, in some cases upon the under side of the umbrella and in others upon the elongated mouth-stalk, which has been compared to the handle of the umbrella.

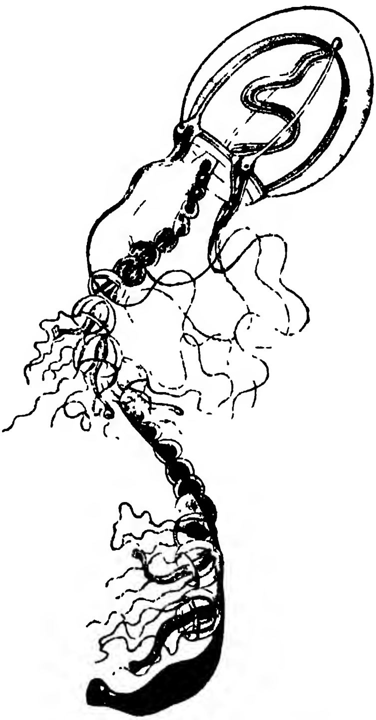


Fig 294.—A Compound Jelly-Fish (*Sarsia*)

This may be regarded as a medusa (of which the large bell or umbrella is seen at upper end of figure) with a very long mouth-stalk (manubrium), on which smaller individuals are formed as buds

Order 2.—Splitting Hydroids (Scyphomedusæ)

To this order belong the large jelly-fish which are often seen in great numbers in British seas during the warmer parts

of the year. The edge of the umbrella is lobed, the notches between the lobes sheltering peculiar sense organs formed by the modification of tentacles and covered by little lappets. Hence the term "covered-eyed medusæ" sometimes applied to these forms, to distinguish them from the "naked-eyed medusæ" of the preceding class, in which the marginal sense organs are not covered by such lappets. These terms, however, were not happily chosen, for it is only in certain cases that the sense organs have to do with sight. A negative characteristic of the jelly-fish included in this division is to be found in the absence of the true velum (see p. 479). The most typical members of the group present two stages in the life-history, as in Obelia (p. 480), *i.e.* (1) a fixed hydroid stage, and (2) the free-swimming medusa. The common British form *Aurelia* may be taken as an example (fig. 295). Here the fixed stage is what is called a *Hydra-tuba*, somewhat resembling a short, broad Hydra in shape, though internally it presents a difference in the presence of four longitudinal folds which project into the digestive cavity. Medusæ are developed from it, not by budding, but by a process of transverse splitting, and when the process is far advanced, the incipient medusæ may be compared to a pile of saucers. Sooner or later these become detached and grow into the mature jelly-fish, by which eggs are produced which complete the cycle of development by becoming hydra-tubæ.

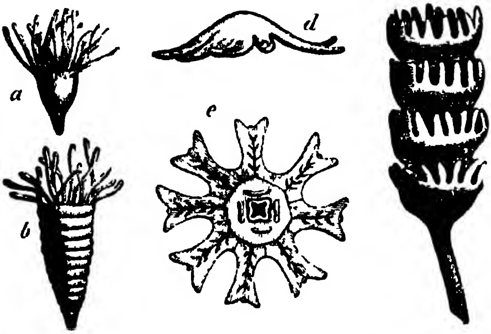


Fig. 295.—Development of Aurelia, enlarged.
a, The fixed stage (hydra-tuba); *b* and *c*, Transverse splitting of *a* to form medusæ; *d* and *e*, Young medusa, seen from the side and from below.

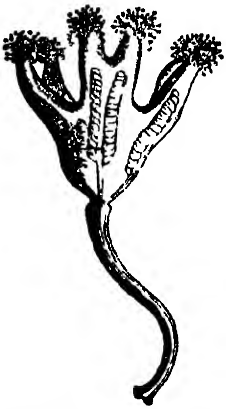


Fig. 296.—Lucernaria, enlarged.

Some of the medusæ belonging to the order have no fixed stage, and in the case of certain other species (*Haliclystus*,

Lucernaria, &c.) there is, on the contrary, no medusa stage (fig. 296).

CLASS III.—COMB JELLY-FISH (CTENOPHORA)

These are small, transparent, free-swimming forms occurring in vast numbers in the open sea. When alive they are of extreme beauty. A common British genus, *Cydippe*, typically exhibits the features of the class (fig. 297).

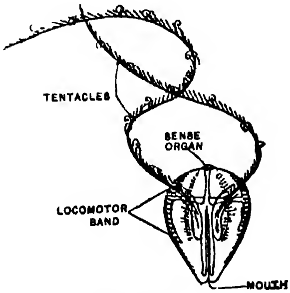


FIG 297.—Cydippe

Here the body may be compared in shape to a minute melon, with the *mouth-opening* at one pole and a complex *sense organ* at the other. Locomotion is brought about by eight longitudinal bands of little paddles which suggest the teeth of a comb. Each *paddle* is apparently made up of a number of cilia which have fused together. From each side of the body a long feathery *tentacle* can be protruded, which is used for the capture of food. These tentacles, when not in use, are drawn back into pouches. The *mouth* leads into a gullet, and that into a complex system of canals, which communicate with the exterior by two pores at the opposite end of the body. Nettling-cells are absent, but the tentacles are provided with glutincus adhesive cells by which particles of food are secured. There is no fixed stage in the life-history.

Among other genera may be mentioned *Venus's Girdle* (*Cestus*), in which the body is band-shaped and may be as much as a foot in length; and *Beroë*, a cap-shaped form devoid of tentacles. There are also two very interesting creeping genera (*Ctenoplana* and *Cœloplana*), which, as a result of their mode of life (see p. 23), present an approach to bilateral symmetry, and have been compared to some of the Turbellarian worms (p. 445), it even being suggested that the Turbellaria have been derived from ancestral forms closely related to the Ctenophores.

SPONGES (PORIFERA)

Sponges were long considered to be of vegetable nature, an idea that was only finally upset by the study of their minute structure. Except to a naturalist the word "sponge" merely suggests a bath-sponge, which is in reality the horny skeleton of a colonial species. To gain a clear idea of the structure of the group it is necessary to consider the simpler cases presented by some of the solitary forms. In the simplest of these the body is shaped like a cup or vase, fixed at one end and open at the other. It is tempting to draw a comparison with Hydra, or better with Protohydra (p. 480), which is simply a tube open at one end. Such a comparison, however, is beset with difficulties, for while in Protohydra the aperture is clearly a mouth through which food is introduced, it will be found by watching the living sponge that currents of water are constantly flowing out of the corresponding opening, here technically known as the *osculum* (L. for little mouth). And, further, the body-wall of the sponge is perforated by numerous small holes through which water-currents set into the central digestive cavity. These currents are the result of ciliary action, and by their means the animal is provided with the food and oxygen it requires, while the various products of waste are swept out to the exterior through the osculum. This mode of life is associated with the sedentary or fixed habit of sponges, which is the chief reason for the old mistake of considering these creatures of vegetable nature.

Microscopic examination shows that the thin body-wall of the simple sponge consists of an external ectoderm made up of a layer of flattened cells, a middle supporting layer, and an internal layer of entoderm composed of *collar-cells*. Each of these cells is provided with a whip-like projection of protoplasm (*flagellum*) (see p. 471), at the base of which is a collar-like projection. By the lashing movements which these threads execute the water-currents upon which the life of the animal depends are produced. The middle supporting layer is comparable to the similarly-placed gelatinous layer of a jelly-fish, and it contains numerous cells of various kinds which have been derived from the ectoderm and entoderm. Some of these

cells produce three-rayed calcareous spicules which form a very characteristic skeleton (fig. 298).

The majority of sponges, like corals (p. 476), are able to produce colonies of the most varied shape by processes of budding or splitting, and in such cases the boundaries between the individuals are usually very ill-marked, though the number of these

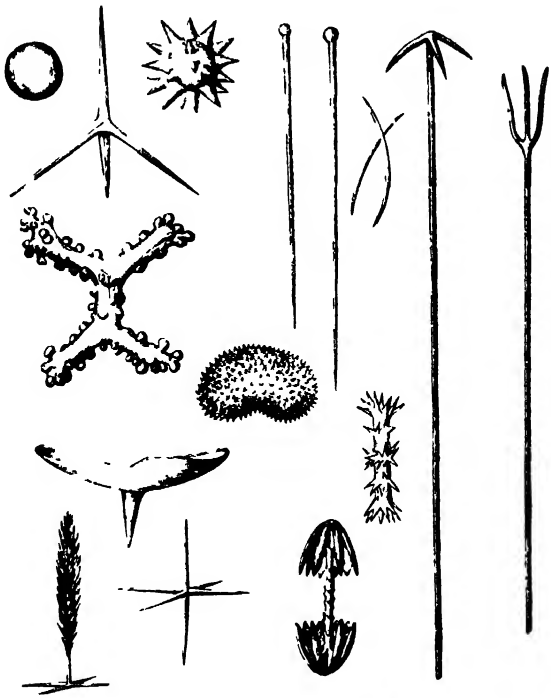


Fig 298 —Sponge Spicules, enlarged

is generally to be told by counting the number of larger openings or oscula which are present. There is also a very large amount of variation in the nature of the skeleton and the extent to which it is developed. It may, as in the simple case described, be made up of scattered spicules, and these may either be calcareous or siliceous. Such spicules are of many different shapes (fig. 298), and they may be compacted into a firm, continuous mass, while they may further be associated with, or replaced by, a complex horny net-work. It should further be remarked that in the large majority of cases the body-wall is much more complicated than

in the case described, and the collar-cells are restricted to small rounded chambers situated in the thickness of the wall and communicating by narrow canals with the exterior on the one hand and the central cavity on the other. The canal system may be exceedingly complex, as may be realized by looking at the labyrinth of spaces present in an ordinary bath-sponge.

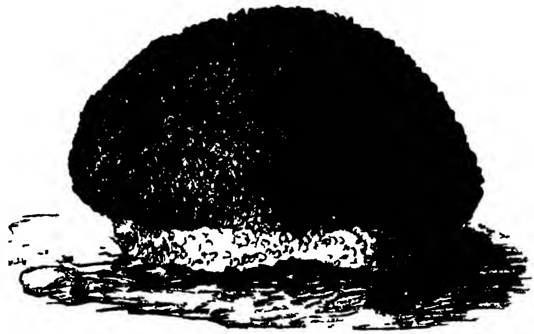


Fig 299 Bath Sponge (*Euspongia*, reduced

It will be sufficient for the present purpose to consider the Sponges as divided into two groups according to the nature of the skeleton, *i.e.*: 1. Calcareous Sponges, and 2. Siliceous Sponges.

1. *Calcareous Sponges*, when simple, correspond to the type described. A more complex example is afforded by the common British species *Grantia compressa*, a small white flattened sponge about an inch long, frequently found attached to stones and other objects between tide-marks. Other forms are represented in fig. 300.

2. *Siliceous Sponges* include a great variety of forms in which the supporting spicules, when present, are of siliceous or flinty nature. One of the commonest British species is the *Bread-crumb Sponge* (*Halichondria*), which, in the form of yellowish-brown or orange-coloured masses, may be found encrusting rocks near low-tide mark. On the surface of the sponge a number of little conical elevations may be seen, and on the end of each an *osculum* is situated. The *pores* by which currents enter are placed in the part of the sponge between these projections. For beauty of form nothing can surpass *Venus's Flower-Basket* (*Euplectella*), a deep-water form in which the skeleton may be compared to a cornucopia with a wall of lace-like appearance and a perforated lid. Another very interesting kind is the *Glass-rope Sponge* (*Hyalonema*) dredged in deep water off Japan. Here the ovoid body is anchored in the mud by bundles of long twisted spicules which have suggested the name.

The *Bath-Sponge* (*Euspongia*) possesses a horny skeleton, the texture of which makes it useful for a variety of purposes.

One small group of sponges is found in *fresh water*, and of

Fig 300 —Group of Calcareous Sponges 1, *Leucandra aspera* 2, *Sycandra raphanus*

these the commonest British genus (*Spongilla*) is found as a greenish crust upon various objects.

ANIMALCULES (Protozoa)

The innumerable host of simple animals which constitute this phylum are nearly all minute, while many of them can only be studied by the highest powers of the microscope, so that every improvement in the construction of that instrument has been followed by the acquisition of fresh knowledge concerning this group. Very great interest attaches to the study of the Protozoa, for here we have to deal with life under the simplest conditions, and find the actual living substance, ***protoplasm***, which

constitutes the essential part of all organisms, in a comparatively pure form, and not obscured to the same extent as in higher animals by the products of its own activity. It has become a tradition to take as a first type one of the simplest members of the group, *i.e.* the *Proteus Animalcule* or *Amœba*, which is commonly found creeping on the mud of ponds.

Reference has frequently been made to the microscopic bodies known as white or colourless corpuscles which abound in the blood and lymph of higher animals (see p. 41). These crawl through the body in all directions and perform various functions of no mean importance, one being that of destroying disease germs which have entered the organism from the exterior. These corpuscles may almost be said to lead an existence independent of the rest of the body, and indeed it is possible to keep them alive outside the organism to which they belong for some time, especially in the case of cold-blooded creatures such as the Frog. An Amœba resembles in many essential respects one of these corpuscles, so much so that when it cannot be obtained for study in the laboratory a white corpuscle is often taken as the best substitute. The body (fig. 301) consists of a particle of semi-fluid protoplasm possessing the power of active locomotion, employed in the search for *food*, which consists of microscopic plants and other solid bodies of organic nature. The complex and solid nature of the food, or part of it, is, as will be elsewhere shown, a characteristic of average animals as compared with average plants, and the powers of locomotion with which most animals are endowed has an obvious relation to this. In such a *fixed animal* as a sponge there is, as we have seen, a special arrangement by which food is brought to the body, compensating for the absence of locomotor powers. An ordinary *green plant*, feeding as it does upon gaseous and liquid food extracted from air and soil, has no need for powers of locomotion, and its branching form gives a very large surface through which the simple food can diffuse. An active *animal*, on the other hand, such as Amœba, has a compact body which is clearly more convenient for locomotor purposes and less exposed than a branching form would be to the attacks of enemies. When tree-like organisms, such as zoophytes, are of animal nature, they usually represent fixed colonies to which food is brought by currents.

The body of a living Amœba is seen to be constantly changing

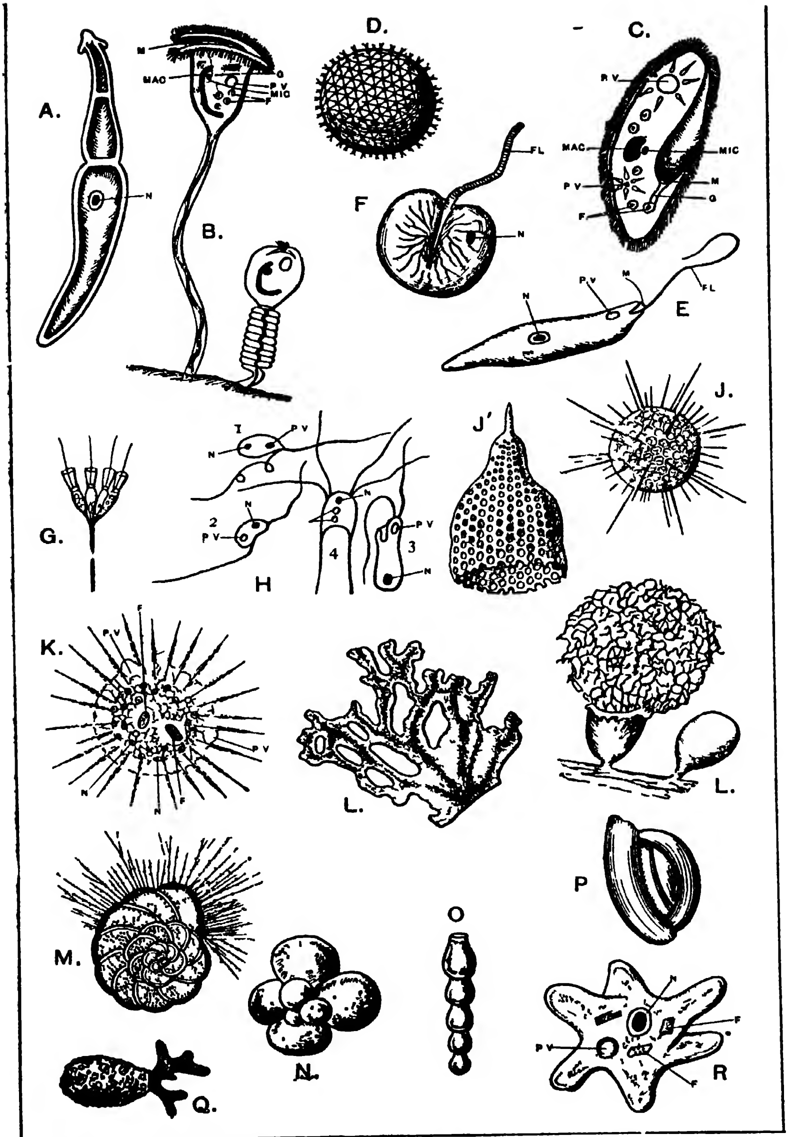


Fig 301 —Protozoa enlarged to various scales Reference letters —F Food FL, flagellum G gullet M, mouth MAC, macronucleus MIC., micronucleus N, nucleus P V pulsating vacuole

A, Cockroach Gregarine (*Clepsidrina blattarum*) B, Bell Animalcule (*Vorticella*) extended and retracted C, Slipper Animalcule (*Paramaecium*) D Volvox. E. Euglena F, Noctiluca. G, Codonocladium H, Monads 1 and 2, Springing Monad (*Heteromita*) 3, *Chilomonas* 4 *Hexamita* J and J' Skeletons of Radiolaria (*Heliosphæra* and *Eucyrtidium*). K, A Sun Animalcule (*Actinosphærium*) L and L Small piece of a Mycetozoon and two capsules (one ruptured) of same. M, A Foraminifer (*Rotalia*), with protruded threads of protoplasm N O P, Shells of Foraminifera (*Globigerina*, *Nodosaria* and *Miliola*) Q, A shell bearing Rhizopod (*Difflugia*) allied to Amœba. R, Proteus Animalcule (*Amœba*)

its shape, blunt lobes of the protoplasm (pseudopods) being protruded from time to time. They are not constant structures, but can be formed and again obliterated at any part of the body—at least in the commonest species of Amœba. Not only do these lobes enable the animal to crawl about, but they also serve to secure food particles, engulfing them, so to speak. No breach is formed thereby, for any hole temporarily made in the semi-fluid protoplasm at once closes up without leaving any trace. Once within the protoplasm the food is digested, and the undigested portions of it are cast out from any part of the body. In the case of Hydra some of the endoderm cells take in and digest solid particles in much the same way (p. 471).

The simple body of Amœba presents but little distinction of parts, but the outer part of the protoplasm is clearer and perhaps somewhat denser than the inner part into which the food is taken, and which also contains, as a rule, numerous granules of various nature. As in a colourless blood corpuscle a small rounded particle of specialized protoplasm, the *nucleus*, can be distinguished, and this appears to have a great deal to do with regulating and controlling the nutrition and other functions. Its presence shows that Amœba is a single *cell* or unit of structure, *i.e.* is unicellular. The body of Hydra, and the same thing is true for all animals higher than the Protozoa, has been compared (p. 469) to a house composed of various building materials of which the units are bricks, blocks of stone, and the like, these materials being likened to the *tissues* of the animal in which *cells* of differing kind are the constituent units. An unicellular creature like Amœba may therefore be compared to a house built of one brick, if such a metaphor can be regarded as thinkable. The PROTOZOA indeed are defined as animals in which the body is made up of one cell only, or at most of an aggregate of cells which are not specialized into tissues, so that each member of the aggregate has to perform all the functions of life. The remaining thirteen phyla of animals are often grouped together as METAZOA, in which the body is made up of more or less numerous cells specialized to form tissues. It may be as well to express this in tabular form, advantage also being taken of the opportunity to show the limits of Vertebrata and Invertebrata, of Diploblastica and Triploblastica.

There can be no doubt that the Metazoa are descended from unicellular forms, which must have resembled some of the

	I.	VERTEBRATA		
	II.	Nemertea		
	III.	Mollusca		
	IV.	Arthropoda		
	V.	Annelida		
	VI.	Gephyrea	Triploblastica	
	VII.	Rotifera		
INVERTEBRATA	VIII.	Molluscoida		
	IX.	Platyhelmia		METAZOA.
	X.	Nemathelmia		
	XI.	Echinodermata		
	XII.	Cœlenterata	Diploblastica	
	XIII.	Porifera		
	XIV.	PROTOZOA		

Protozoa, and consequently great interest attaches to the study of those members of the latter group which are aggregates of cells, since some of these may, in some respects, be like the transitional forms.

Returning to the consideration of Amœba, we find that this differs from a colourless corpuscle in possessing a liquid-filled space within the protoplasm which is constantly changing its size in a regular manner, and is therefore termed a *pulsating vacuole*. If carefully watched in a living specimen placed under the microscope, this will be found to slowly expand to a certain size and then to suddenly contract so as to be entirely lost to view, soon reappearing, however, at the same spot. It appears to communicate with the exterior, and probably has to do with getting rid of waste products (*excretion*) and perhaps also with the introduction of dissolved oxygen into the body for the purpose of *respiration*.

Amœba is *sensitive* to external influences, being affected, for example, by changes of temperature, but it also appears to be able to execute movements, apart from the direct action of such influences. Otherwise expressed, the minute fragment of protoplasm which constitutes the body of this animal, performs those functions which, in higher forms, are relegated to a *nervous system*, and its connected *sense organs*.

Careful observation has shown that Amœba multiplies itself by a process of splitting or *fission*, as observed in some animals higher in the scale (pp. 476). The nucleus elongates, and becomes divided into two parts, and at the same time the rest of the body is halved, the result being that the parent animal disappears altogether as an individual, being replaced by two new animals which subsequently increase in size.

It therefore appears that all the functions of life can be, and are, performed by a single cell, this having to discharge the duties which in higher organisms are distributed between different complex organs and tissues.

It is convenient to divide the Protozoa into three groups:— 1. Infusorians (Infusoria); 2. Amœba-like Protozoa (Rhizopoda); and 3. Gregarines (Sporozoa)

Group 1.—Infusorians (Infusoria)

If boiling water is added to chopped hay or other vegetable matter, and the infusion so procured allowed to stand for some time, it will begin to putrefy, and a large number of minute active creatures will make their appearance in it. The same thing would happen if the infusion were of animal nature. The term *Infusoria* was first applied to the minute forms noted in various decomposing substances of the kind just mentioned, but they are by no means invariably associated with putridity, and abound both in salt and fresh water, or even on damp soil and vegetation.

A very common form is the *Slipper Animalcule* (*Paramœcium*) (fig. 301), which is readily obtained by making an infusion of hay as described. It is an active whitish creature, just visible to the naked eye. Placed under the microscope, it will be found to possess an elongated body, which, unlike Amœba, has a definite shape owing to the fact that the outer layer of the protoplasm (ectosarc) is firmer than the rest (endosarc), and covered by a thin elastic membrane or *cuticle*. As another consequence of this, food cannot be taken into, or solid waste ejected from, any part of the body, but there is on one side a depression which leads to a *mouth*, and this again into a very short *gullet*, that ends abruptly in the soft internal protoplasm (endosarc). Not far from this depression there is a spot where the cuticle is absent, and the solid refuse from the food can pass out to the exterior.

The presence of a cuticle, and the firm nature of the outer protoplasm, prevent the formation of the blunt lobes (pseudopods), which, as we have seen, serve in Amœba as organs for obtaining food and effecting locomotion. Their place is here taken by a uniform covering of *cilia*, which are protruded through minute holes in the cuticle. By them the animalcule is rowed about from place to place, and they also set up currents by which food particles

are conducted into the mouth. Within the body two *pulsating vacuoles* can be seen, one at each end, and there are also two bodies of nuclear nature, which are placed close together. One of them is large (macronucleus), and the other small (micronucleus). They pass through a series of very complicated changes before the animal undergoes transverse splitting or *fission*, which is here the characteristic method of multiplication.

A very large section of the Infusoria are characterized by the presence of cilia, the arrangement of which differs in different species, and these constitute the group of *Ciliata*. We may take as a second example of this division the *Bell Animalcule* (*Vorticella*) (fig. 301), which is commonly found attached to water-weeds, or it may be to aquatic animals, such as the little red worm Tubifex (p. 431). Here the body is of bluntly conical form, with the narrow end drawn out into a long *stalk*, firmly fixed to the object upon which the animal lives. When fully expanded, it can be seen that the cilia are limited to the broad end of the body, on which they are arranged in a short spiral, while smaller cilia are continued down into a depression, which may be compared to that seen in the Slipper Animalcule, for it leads into a short gullet of the same kind. Within this depression there is a soft spot through which the undigested remains of the food are ejected. The wreath of cilia produces currents, which set into and out of the mouth-depression, carrying food and dissolved oxygen inwards and waste matters outwards. As in a Slipper Animalcule, the protoplasm is divided into a softer central *endosarc* and a firm external *ectosarc*, the latter being continued into a fibre which runs in a wavy manner through the stalk. If Vorticella is alarmed in any way, the free end of the body is folded in and, at the same time, the elastic stalk is thrown into the form of a spiral by the shortening or contraction of the fibre it encloses.

Within the body one *pulsating vacuole* can be seen, and also two *nuclei*, the big one having a very characteristic horse-shoe form. Multiplication is effected by longitudinal splitting, one of the two new individuals remaining on the stalk, while the other becomes detached, being rowed about by the cilia till a suitable spot is reached, when it becomes attached, and develops a new stalk.

Some of the near relatives of the Bell Animalcule form colonies by means of fission, the new individuals remaining attached instead

of at once becoming separated, as in Vorticella. All the members of the colony are of exactly similar nature.

Another large section of Infusorians, the *Flagellata*, is characterized by the presence of those protoplasmic threads known as *flagella* (p. 471), which, though allied to cilia, are capable of executing much more complex movements, and are not present in large numbers on the same cell. A common example is *Euglena* (fig. 301), a minute green form with worm-like body, found, sometimes very abundantly, in stagnant water. At the front end there is one long *flagellum*, which acts as a swimming organ, pulling the body after it through the water. At its base there is a minute *mouth* leading into an exceedingly short *gullet*, near which is a *pulsating vacuole*, and a red *pigment-spot*. The nucleus is central, and the green colouring matter (chlorophyll), which is of the same nature as that found in ordinary plants, is contained in specialized parts of the protoplasm. The body is constantly altering its shape in a peculiar manner, but the presence of a firm *cuticle* prevents the formation of pseudopods.

Putrefying infusions contain vast numbers of very minute flagellates, commonly known as *monads* (fig. 301). A well-known form is the *Springing Monad* (*Heteromita*), so named from the character of its movements. It is shaped like a bean, and possesses two long *flagella*, attached near the notched side. One of these is extended forward during locomotion like the single flagellum of Euglena, while the other is trailed behind.

A very interesting section of the present group contains simple and colonial forms, in which the individuals closely resemble the *collar-cells* of sponges (see p. 484). *Codonocladium* (fig. 301) may be taken as an example. The interest chiefly lies in the fact that such forms perhaps give a hint as to the ancestry of the sponges.

It has been mentioned that Euglena is like a green plant, inasmuch as it contains chlorophyll, but the presence of a mouth proves it to be an animal. There are, however, certain flagellates which are coloured green by this pigment, and at the same time are devoid of any mouth-opening. Indeed, many botanists claim them as plants. Some are simple, others colonial, and of the latter, one genus is particularly well known on account of its great beauty as a microscopic object. This is *Volvox*, a form shaped like a hollow sphere (fig. 301), and about the size of a very small pin's head. At regular intervals in the wall of the sphere are

imbedded the green pear-shaped individuals, each of which is provided with a pair of *flagella*, and is connected by threads of protoplasm with its neighbours. The colony swims about by means of the flagella, slowly revolving as it does so. We have here an example of the most perfect type of symmetry known, that of the sphere, a shape which is only possible when external influences act on all parts alike, as can only be the case with a revolving aquatic form. At times, however, the symmetry of Volvox is disturbed by the specialization of certain cells for the purpose of propagation.

A small marine group of flagellates is represented by the remarkable form *Noctiluca* (L. *nox*, night; *lux*, light), countless myriads of which are sometimes found floating together in the sea (fig. 301), and are one of the causes of the phosphorescence common in the summer months. Each individual is of comparatively large size ($\frac{1}{25}$ of an inch in diameter) and is shaped like a pouch, a very large *flagellum* being attached at one end of the groove. The *mouth* is situated at the base of this structure and leads into a short *gullet* into which a second but smaller flagellum projects.

Group 2.—Amœba-like Protozoa (Rhizopoda)

A description has already been given of the Proteus Animalcule (Amœba), which may be taken as a type of the group, all the members of which are provided with those projections of the body which are called pseudopods, though it is only in some cases that these are broad lobes, as in many species of Amœba.

There are a number of common fresh-water members of this group (fig. 301), which essentially resemble Amœba except that they possess a shell of varied nature and shape. Sometimes it consists of foreign particles cemented together, and at other times it is entirely made up of material presumably of horny nature formed by the activity of the protoplasm.

Cases like those just mentioned lead on to a large and important group found both in salt and fresh water, and characterized by the presence of a shell that is often riddled with minute pores or *foramina*, on which account the name of *Foraminifera* has been given (fig. 301). The shell may be either tough and membranous, composed of foreign particles agglutinated

together, or, and usually, of calcareous nature. It either consists of a single chamber or of a number of chambers associated in various manners and presenting the utmost variety in form. One of the most abundant forms is *Globigerina*, the shell of which consists of several rounded chambers united together, and which occurs in such profusion in a calcareous deposit covering large tracts of the ocean floor that this has received the name of Globigerina ooze. Globigerina and other forms have also lived in earlier epochs of the earth's history, playing a very important part as rock-builders. The pure form of limestone called chalk is, for example, mainly composed of such remains. Most of the Foraminifera are of small size, but *Nummulina*, so called from its coin-like shape (L. *nummus*, a coin), reaches the size of a shilling piece. Its shells chiefly make up the important nummulitic limestone by which mountain ranges in the Mediterranean region are to a large extent built up.

The *pseudopods* of the Foraminifera are slender threads which often unite together into a sort of net-work. More than one *nucleus* is commonly present in the protoplasm of which the soft body consists.

The *Sun-Animalcules* (*Heliozoa*) (fig. 301) are a group of mainly fresh-water forms in which the body is spherical, and stiff pointed pseudopods radiate from it in a way which suggests the rays seen in the conventional representation of the sun; hence the name. There may be more than one nucleus and pulsating vacuole. *Actinophrys* and *Actinosphærium* are typical genera. In some members of the group the surface of the body is covered by loose flinty *spicules*, and in the stalked genus *Clathrulina* there is a continuous shell in the form of a perforated hollow sphere. This leads on to the condition found in most of the marine group of *Ray-Animalcules* (Radiolaria) (fig. 301), where there is a siliceous shell of extreme beauty and of the most varied shape. Some parts of the sea-floor are covered by Radiolarian ooze, mainly composed of such shells; and there are also fossil forms making up certain rocks, notably in the Barbados. Almost every microscopic cabinet contains a slide of this "Barbados earth".

The Amœba group may be reckoned to include certain problematic organisms called Myxomycetes or *Mycetozoa*, the latter name indicating the doubt which has existed as to whether

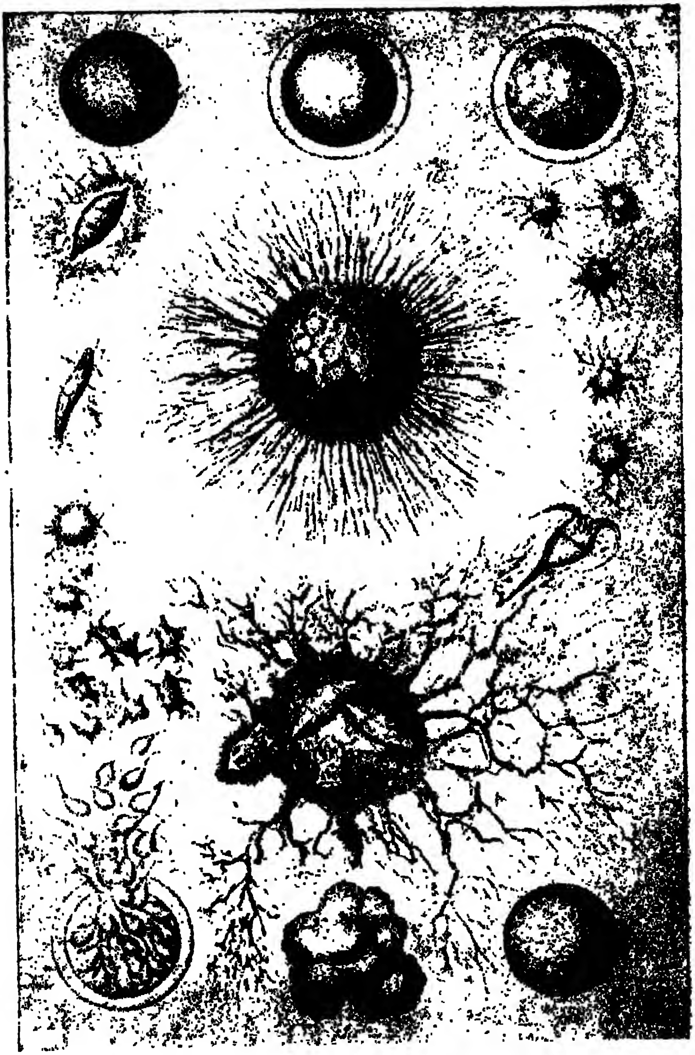


Fig. 302.—Stages in Life-History of *Protomyxa*, enlarged

1, Spherical resting stage; 2, the same invested with firm coat; 3, contents of same dividing into spores; 4, escape of spores (5), which assume amœba-like shape, feed (9 and 10), and fuse together (13, 14) to form adult stage, which is shown in hungry stage (11), and feeding (12). This ultimately contracts (15), and becomes round (16), after which the life-cycle recommences as before

they are plants or animals (Gk. *mykēs*, a fungus; *zōon*, an animal). Indeed, like Volvox and its allies, they will be found described in most text-books, both of botany and zoology. A good example is the so-called "flowers of tan" (*Æthalium*) (fig. 301), which is to be found in the form of sulphur-coloured net-works of protoplasm creeping slowly over heaps of spent tan, and attaining a considerable size. At a certain time this organism produces little capsules in which a number of small hard-coated reproductive bodies known as *spores* are formed. From these escape little fragments of protoplasm, which are at first something like flagellate protozoans, for each of them possesses a single flagellum, while later on they assume the shape of minute amœbæ. A number of these fuse together to form a creeping net-work.

In the Amœba group we may also include one of the simplest known kinds of Protozoa, a minute marine animal—*Protomyxa aurantiaca* (fig. 302)—found on the coast of the Canary Islands. In colour and appearance it resembles a small individual of the tan-flower organism, but no trace of a nucleus was observed by its discoverer. After leading an active life for some time the body contracts into a spherical form and becomes surrounded by a firm investment. The protoplasm then divides up into a number of fragments, each of which possesses a single flagellum. These are liberated by the rupture of the protecting investment, soon assuming the shape of little amœbæ, of which numbers fuse together to form an adult.

Group 3.—GREGARINES (Sporozoa)

This third and last group of the Protozoa has been modified by the parasitic habit. The body is covered by a firm cuticle, but cilia as well as pseudopods are absent. A good example is a form (*Clepsidrina blattarum*) (fig. 301), found within the alimentary canal of the Cockroach. The elongated body, when very young, is attached by a hooked narrower end to the lining of the cockroach's intestine. Later on, the hooked end is shed, the animal becoming free. A *nucleus* is discernible within the protoplasm, but no pulsating vacuole. As the name indicates, the group is characterized by the presence of those specialized reproductive cells called *spores*, which are more commonly met with in plants

than in animals. Before these can be formed two individuals must together be surrounded by a firm coating or *cyst*, and they then break up into a multitude of little spores surrounded by firm coats. The spores become free by a somewhat complex process, the firm coat of each then ruptures, and the contained protoplasm emerges, ultimately growing into an adult Gregarine, which is at first imbedded in and nourished by one of the cells lining the intestine of the cockroach.

The Sporozoa not only include many forms more or less similar to the one described, but also a large number of much simpler species, parasitic in the cells of Vertebrates and other higher animals.

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